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Chinese Regional Agricultural Productivity: 1994-2005

Haizhi Tong
University of Nebraska, haizhitong@yahoo.com

Lilyan E. Fulginiti
University of Nebraska-Lincoln, lfulginiti1@unl.edu

Juan P. Sesmero
University of Nebraksa, juampase@hotmail.com

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Lilyan E. Fulginiti
Juan P. Sesmero[1]

Abstract. Agricultural productivity growth in Chinese provinces during the 1994-2005 period is examined using two alternative approaches: a parametric stochastic frontier and a non-parametric Malmquist index. These models are suitable to the Chinese situation due to the existence of procurement prices, quotas, and other interventions that have distorted prices. Results show that there is high but declining productivity growth rates in the mid 1990's with productivity growth decreasing in the late 1990's but with a reversal of the trend around 1998 when growth rates start accelerating. A stochastic frontier translog production function is estimated to obtain an alternative measure of total factor productivity growth. Results are compared across these two models. Although average growth in technical change is similar in the two models, the regional rates are dissimilar. A model that includes three variables hypothesized to explain the difference in performance across regions is also estimated. The three variables included in the model are irrigation ratio, illiterate ratio and agriculture expenditure level. These variables make allowance for the difference of land and labor quality and the effect of public inputs. The irrigation ratio and agriculture expenditure are found to positively relate to the technical efficiency change and the illiterate ratio is found to negatively relate to the technical efficiency change. The results are consistent with expectations.

Keywords: TFP growth, stochastic production frontier, Malmquist index,provincial TFP.

JEL Classification: O4, O5, Q1

[1] Department of Agricultural Economics. University of Nebraksa, Lincoln, NE 68583-0922.

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I. Introduction

Since the economic reforms of 1978, China's agricultural sector has had an impressive performance. According to China's statistical yearbook, in 2005 the gross output value of farming, forestry, animal industry and fishery at current values, was around 3.9 trillion Yuan, while in 1978 the gross output value of agriculture was only 0.13 trillion Yuan. Figure 1 shows the trend of gross output value in agriculture since 1978 in current Yuans.

The following facts[2] may give some idea of the importance of agriculture in China.

- China's total population was 1,314 billion people at the end of 2005
- 69 percent of China's people live in rural areas
- China is fourth in the world in land area
- China has 9 percent of the world's total arable land, and 20 percent of the world's population.

The study of China's agricultural sector growth is attractive given the rapid expansion of production and the reforms introduced in this sector. Many studies have examined agricultural growth of China. The studies can be divided by the time period of analysis into two sets. The first set covers the 1980's. The second set refers to the 1990's with a couple of studies (Tong and Fulginiti, 2003, Dekle et al., 2006, Bosworth et al., 2008, and Nin Pratt et al., 2009) extending to 2003 and 2004. During the 1980's, China's agricultural output and productivity experienced very rapid growth. Growth seems to have slowed down in the 1990's to pick up again in the 2000's. Most other studies have

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[2] From ERS in USDA website.

focused on aggregate productivity at the national level while the main purpose of this paper is to explore differential agricultural productivity growth at the regional level.

This paper's objective is to examine regional agricultural productivity growth in China during the 1994-2005 period using radically different methods and focusing on performance at the provincial level. This involves three steps: a) measurement using a Malmquist index method, b) measurement using a stochastic frontier production function, and c) identification of particular factors that might have contributed to productivity change.

The reason for examining productivity growth at the provincial level is that averages, including national aggregates might disguise important differential trends across regions. Most studies have used FAO data at the national level to do the estimation and it does not allow analysis of differential performance across provinces. China is a country with diverse ecosystems and with a large share of the population working on agriculture, in particular in the Central and Western provinces. It would be of interest to identify which regions have grown faster and how this growth compares across provinces. There is also a wealth of information at the provincial level that lends itself to this analysis and provides detailed information about regional production systems. When using cross regional data, the analysis is affected by different institutions prevailing in different regions. However in China, the political environment across regions has been similar. This allows extraction of sources of growth beyond "institutional factors." This is important because past studies have reported this as the main contributor of economic growth in China.

The Malmquist index and a stochastic frontier production function are particularly suitable to examine China's agricultural productivity because they rely on quantity data only. There is no need to use prices, which is an advantage given that they were distorted due to government intervention. Compared with a production function, the Malmquist index does not suffer from specification error. But the disadvantage of this index is that it is nonstochastic and therefore very sensitive to errors. We use the contemporaneous version of this index which only uses information on consecutive years. A stochastic frontier translog production function is also used to estimate the production structure of Chinese agriculture and its productivity growth rate. This method is not so vulnerable to outliers, and it uses information across the full spectrum of time and space, but it has the disadvantage of specification error. The estimates across these disparate methods are then compared and it is this comparison the main source of understanding of the evolution of TFP growth rates in Chinese agriculture.

Both the Malmquist Index and the stochastic frontier production function show that productivity growth in Chinese agriculture has been higher in the mid 1990's than in the late 1990's. There is also indication of a reversal in this trend with improvements in the 2000's.

A literature review is found in section II. Section III has a brief background on China's agricultural sector policies and the reforms during since the 1980's. Section IV reports the Malmquist index results. Section V reports the outcome from the stochastic frontier production function. Section VI and VII presents a critical analysis of results across methodologies in this study and across studies in the literature. Section VIII extends one of the approaches to include potential explanations for differential growth across provinces and section IX concludes.

II. Literature Review

As mentioned above, we find numerous studies of agricultural productivity growth in China. They have covered different periods, different aggregation levels, used different data sets and different methodologies. We summarize here the most recent ones and those that are more relevant to our study.

McMillan, Whalley and Zhu (1989) examined the effects of price increases and the introduction of HRS (household responsibility system) on agricultural performance from 1978 to 1984. They set up an "institutional" production function and found that both factors were major contributors to TFP growth.

Fan (1991) used a frontier production function to separate agricultural growth into input growth, technical change, institutional reform, and efficiency change. Lambert et al. (1998) also calculated productivity growth in Chinese agriculture and its sources by constructing Divisa indices for the period 1979-1995. Fan and Zhang (2001) used a generalized maximum entropy approach to estimate a multi output production technology for twenty-five provinces during the period of 1979-1996. Wu et al. (2001) constructed provincial and national Malmquist Indices to calculate TFP growth and decompose it into technical change and efficiency change during the period 1980-1995. These studies found an increase in TFP up until the mid 1980's and a decrease thereafter.

Lin (1992) employed a fixed effects model (using provincial level data) to evaluate the effects of decollectivization (HRS), price adjustments and other factors on productivity growth. Lin (1993) tackled the issue of efficiency of different systems and showed that household farms outperformed cooperative farms, which gave support for institutional reform in China. In yet another study, Lin (1995) examined rice production and tested the induced institutional innovation theory. Huang and Rozelle (1995) used a fixed effects model and data from 1952 to 1990 and found that environmental stress was an important factor in reducing TFP growth after the mid 1980's.

Regarding the role of market institutions and transaction costs on productivity, Rozelle, Park, Huang and Jin (1997) examined market integration after the implementation of liberalized economic policies in food markets. Rozelle, Taylor and DeBrauw (1999) used a labor migration framework to model the effect of migration and remittances on agricultural productivity growth in China. DeBrauw, Huang and Rozelle (2000) examined how market liberalization influenced the behavior of producers.

Zhang and Carter (1997) constructed a Cobb-Douglas production function to separate the contribution of inputs, weather and efficiency to growth of grain production from 1980 to 1990. Lezin et al. (2005) also estimated a Cobb Douglas production function for the province of Zhejiang and found that labor, capital and land had positive impacts on agricultural productivity growth. Colby, Diao and Somwaru (2000) used a Tornqvist Index to analyze the sources of output growth in total grain and in four major crops in China (rice, wheat, corn and soybean). Fan and Zhang (2002) adjusted previous measures of growth in outputs and inputs and calculated a Tornquist-Theil index of TFP at the national and provincial levels for the period 1952-1997. In particular, they found an increase in TFP during the period 1978-1997.

Jin et al. (2002) discussed the impact of investment in research in agricultural productivity. They found that new technologies are the main drivers of agricultural productivity growth in the period 1980-1995. Hsu et al. (2003) calculate output-orientated Malmquist productivity indexes and its decompositions using a non-parametric DEA (Data Envelopment Analysis) approach covering the period 1984-1999. Mead (2003) reexamines data on Chinese agricultural productivity growth using an alternative calculation of China's labor force. This estimate is employed in a TFP calculation based on a constant-returns-to-scale Cobb Douglas production function. He finds a strong correlation between policies and productivity growth and 1984-1999.

Dekle et al. (2006) and Bosworth et al. (2008) calculate productivity growth in China as a residual based on a constant-returns-to-scale Cobb Douglas approximation to the technology. Dekle decomposed productivity growth in the period 1978-2003 into contributions from the agricultural sector, the public and private non-agricultural sector, and reallocations of the labor force from low productivity sectors to high productivity sectors. Bosworth et al. calculate average national productivity of China and India and compare their performance in the period 1978-2004.

Many authors have calculated Chinese agricultural productivity growth based on data from FAO and within a multi-country context. Nin Pratt, Yu and Fan used data from the statistical database of the Food and Agriculture Organization of the United Nations (FAO, 2007) to calculate both a Tornquist-Theil Index and a Malmquist Index of TFP for China and India. The Malmquist index was calculated based on distances to a frontier constructed based on 59 countries. They found an increase in Chinese agricultural productivity in the post-reform period up until 2003. Positive productivity growth was consistent across methods. They also found that both efficiency and technical change were important drivers of productivity growth and that returns to agricultural R&D are high. Coelli and Rao also used a DEA approach to Malmquist indices of TFP for many countries based on data from

FAO for the period 1980-2000. They found that agricultural TFP in China grew at an average yearly rate of 1.06% in this period. Bravo-Ortega and Lederman (2004) calculate agricultural TFP growth for China (among other countries) using data from FAO for the period 1961-2000. They estimate a translog production function and calculate TFP as a residual. They found that the Chinese agricultural TFP growth averaged a strong 1.67 in this period. Ludena et al. constructed TFP indices for Chinese agriculture based on a DEA directional distance function. Using data from FAO, they calculated an average agricultural TFP growth of 1.67 for the period 1961-2000, which exactly coincides with that of Bravo-Ortega and Lederman.

Based on the above studies, we learn that:

1) Studies have used data from the Chinese Statistical Yearbook, and from FAO. In general, studies that use FAO data show higher TFP growth rates for 1970-2000.
2) Methodologies used include econometric estimation of production functions, some of them being stochastic frontiers, growth accounting TFP indices, and data envelopment analysis (DEA).
3) The most recent studies cover different periods that extend from the time when policy reforms were introduced up until the 2000's.
4) Estimates indicate that agricultural productivity growth in China was higher immediately after the introduction of the Household Responsibility System (HRS, from 1978 to mid 80's) making institutional reform the main contributor to TFP growth in that period. However, there is evidence that TFP growth slowed down after that period and towards the end of 1990's which may be due to exhaustion of the institutional effect, the introduction of the procurement price

system, environmental stress, and lack of agriculture investments and innovations that hindered further grain in productivity growth. The most recent studies show a trend reversal and a slight recovery of productivity growth in the early 2000's.

III. China's Agricultural Policies

Before 1978, agriculture in China was under a collective system. After 1978, China adopted the "household production responsibility system (HRS)". Under HRS system, although farmland is not privately owned, peasants can have long term use rights to land. They are also free to allocate resources as they see fit but need to deliver a quota to the government at procurement prices. The leftover output is traded freely in the market. Of course peasants also need to pay taxes and local fees. Local government is responsible for some extension services and the introduction of new technologies and seed varieties.

China's agricultural policies have experienced quite a bit of change over the last 20 years. China has undergone a reform from a planning economy to a market economy. There has been elimination of government intervention to facilitate the role of market forces. The first biggest step in China's agricultural reform was the introduction of HRS in 1978. HRS motivated farmers to pursue profit. This system gave farmers the incentives to reduce costs and adopt new technologies. Another very important reform happened at the beginning of 1990's (1993), when China abandoned the food rationing system. Under the grain-rationing system, urban consumers used coupons to buy a fixed amount of grain at a low price. To buy more they have to pay the market price that is usually higher. Due to budget pressures, the government reduced the gap between the controlled and the market price in 1991 and 1992. Seeing no resistance from urban consumers, the government finally eliminated the price controls in early 1994.

The government also has different policies for different agricultural products. The government has relative less intervention in the fruits, vegetables and livestock markets and much more intervention on grain production.

An important reform introduced in 1995 called the Grain-Bag responsibility system requires leaders in each province to maintain overall balance of grain supply and demand within each province and to regulate local markets. This policy advocates self-sufficiency in grain production. The result of the Grain-Bag policy is that grain output has increased due to reallocation of land and other agricultural inputs to grains.[3] This policy may introduce some inefficiency in resource allocation due to regional protectionism.

More recently, two important reforms aimed at reducing inefficiencies were introduced. In 1998 a second HRS wave replaced the one introduced in 1978 as the twenty year land leases expired and were replaced by new and more durable ones.
In 2003, the new administration of Wen Jiabao eliminated taxes in the farming sector.

IV. The Malmquist Index

We used provincial data for years 1993-2005 to construct a Malmquist productivity index. The Malmquist index is a non-parametric, nonstochastic index used to examine productivity change. Productivity refers to output per unit of input and can be measured by dividing an output index by an input index. We care about productivity because it indicates an increase in output for given resources.

Because the Malmquist index is quantity based, it is more suitable to China's

[3] China's Grain Policy at a Crossroads, Economic Research Service/USDA.

situation due to the existence of procurement prices and quotas. As specified by Färe et al. (1994) this index is:

$$M_0(x_{t+1}, y_{t+1}, x_t, y_t) = [\frac{D_o^t(x_{t+1}, y_{t+1})}{D_0^t(x_t, y_t)} * \frac{D_o^{t+1}(x_{t+1}, y_{t+1})}{D_0^{t+1}(x_t, y_t)}]^{1/2} \qquad (1)$$

The subscript O shows that this is an output oriented Malmquist index. Here D_o refers to an output distance function. D_o is calculated as follows.[4]

$$[D^t{}_o(x_t, y_t)]^{-1} = \max_{\phi,\lambda,} \phi,$$

$$\text{st.} \quad -\phi y_{it} + Y_t\lambda \geq 0,$$

$$x_{it} - X_t\lambda \geq 0,$$

$$\lambda \geq 0$$

where *x* and *y* are input and output vectors respectively. *X (K*N)* and *Y (M*N)* are the input and output matrixes respectively. λ is a *N*1* vector of constants. Here $1 =< \phi < \infty$ and $\phi - 1$ is the proportional increase in outputs that could be achieved by the *i-th* region, with input quantities held constant. Färe et al. also show that the index can be factored into efficiency change and technical change, which is a geometric mean of technologies in two periods:

$$M_0(x_{t+1}, y_{t+1}, x_t, y_t) = \frac{D_o^{t+1}(x_{t+1}, y_{t+1})}{D_0^t(x_t, y_t)} [\frac{D_o^t(x_{t+1}, y_{t+1})}{D_0^{t+1}(x_{t+1}, y_{t+1})} * \frac{D_o^t(x_t, y_t)}{D_0^{t+1}(x_t, y_t)}]^{1/2} \qquad (2)$$

Technical efficiency change tells us whether a particular region is moving closer to the frontier or further away from the frontier. Technical change refers to a shift of the frontier. Indexes smaller than one represent inefficiency and regressive technical change.

[4] Coelli 1996, pp. 27.

In this paper the Data Envelopment Analysis (Computer) Program (DEAP) developed by Tim Coelli is used to calculate the Malmquist Index. All the data used in the construction of this index are from China Statistical Yearbook (CSY). We use agricultural output[5] in real Yuans for 29 provinces during 1993-2005.

There are four inputs: total sown areas of agricultural products (in thousands hectares), agricultural machinery (in 10 thousand KW), labor (in 10 thousand persons), and fertilizer (in 10 thousands tons.) Fertilizer includes Nitrogenous fertilizer, Phosphate fertilizer, Potash fertilizer and compound fertilizer. Figure 2 summarizes the data. Data by province is available from the authors.

According to the discussion in section 2, Chinese agricultural productivity studies have used two main sources of data. A few studies, including this one, have obtained data directly from the Chinese Statistical Yearbook, described in Figure 2. Most other studies have relied on FAO for information. Figure 3 describes the evolution FAO data.[6] There are two important differences across these data sources. Output from CSY shows an increase until 1997, a slight decrease in 1997-2003, increasing again from 2004 on, while FAO's output shows sustained increases throughout the period. There are also differences in the evolution of the fertilizer aggregate and of labor. The difference in evolution of variables used might lead to different productivity estimates.

As mentioned before, the Malmquist index is very sensitive to outliers. The data for Tibet seems very irregular so this region is deleted from the data set for this analysis. Table 1a reports the mean productivity change for the aggregate of all provinces, except Tibet, by year. Table 2 reports the mean productivity index for each province. The

[5] It is the gross output value of whole agriculture sector, which includes farming, forestry, animal industry and fishery.
[6] Data provided by Ludena et al.

technical change and efficiency change components by year and province are included in Appendix 3 and the TFP evolution by province can be seen in Appendix 6.

All the means reported are weighted[7] geometric means. The last column is the Malmquist productivity index, which measures total factor productivity change (tfp change). This can be decomposed into efficiency change and technical change. Efficiency change refers to movements towards the frontier, also referred to as "catch up." Technical change represents shifts of the frontier of production or innovations.

Table 1a shows that, according to the Malmquist Index, China experienced very high productivity growth in 1994 and 1995 [(tfpch-1)*100 is the productivity growth]. From 1996 to 1998, the agricultural sector shows TFP decreasing with a reversal of this trend in 1999, when it starts increasing again. The trend becomes positive for the years 2003-2005. On average, total factor productivity growth in Chinese agriculture during 1994-2005 was a robust 1.6% annually, compared to 1.5% to 2% productivity growth in U.S. agriculture during the 1950-2004 period.

From Table 2 (and Appendices 3 and 6) we can see that most regions experienced positive TFP growth. Beijing and Shanghai define the frontier throughout the period and they are the main drivers a frontier shift as the strong rates of technical change indicate. Here Beijing and Shanghai refer the rural area around these two cities. Other regions with good productivity performance are: Hebei, Shanxi, Jiangsu, Zhejiang, Fujian, and Qinghai. The worst performer is Hainan.

[7] Weights are production values.

Figure 4 summarizes the agricultural performance of China, measured by the Malmquist index, by aggregating productivity change in three regions.[8] Detailed information per region is available in Appendix 5.

In all three regions, the TFP rates have been decreasing up to 1998, increasing until 2004 then decreasing again in 2005, the last year of the study. During the period of analysis, the East region has outperformed the other two, except in 1994.[9] Some of the factors that might have affected economic performance during this period are: 1) the elimination of the rationing system in years 1994 and 1995; 2) the steady decline in procurement prices during this period; 3) the introduction of the Gain-Bag Responsibility System in 1995; 4) bad weather conditions in the 90's; 5) the second round of the HRS and the tax exemptions to the agricultural sector implemented by Wen Jiabao's administration; and 6) an increase in technical change due to diffusion of new available technologies.

We remind the reader that the Malmquist is affected by extreme data points and that it is calculated with information of two consecutive years only, as a result showing extreme variability. Averages "hide" information so in depth evaluation should be done by looking at the evolution of the index by province. This information is available in Appendices 3 and 6.

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[8] East includes: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi and Hainan. Central includes: Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan. West includes: Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xingjiang.

[9] It is important here to note that Tibet is not included in the analysis. Tibet seems to be a region with an important improvement in agricultural performance. Inclusion of Tibet in the analysis might change the performance of the West region and possibly these rankings.

V. Stochastic Frontier Translog Production Function

In this section we propose to estimate TFP using Battese and Coelli ‘s (1992) stochastic frontier production function which is specially suited for panel data and is stochastic. The model is expressed as follows.

$$Y_{it} = x_{it}\beta + (V_{it} - U_{it}) \qquad (3)$$

In our case, *i*=1, 2, ……, 30, *t*=1, 2, ……,9.

Here Y_{it} is the logarithm of the output level of the *i-th* province in the *t-th* time period. x_{it} is a *4*1* vector of the logarithm of the input quantities of the *i-th* province in the *t-th* time period. β is the coefficient vector. The V_{it} are random errors which are assumed to be iid N $(0, \sigma_V{}^2)$ and are independent of U_{it}. $U_{it} = (U_i \exp(-\eta(t-T)))$. U_i are iid one sided errors that are assumed to account for technical inefficiency and to be truncated at zero of the N $(\mu, \sigma_V{}^2)$ distributions. And η is a parameter to be estimated.

The following translog production function is used in estimation:

$$\ln Y_{it} = \alpha_0 + \sum_m \alpha_m \ln x_{mit} + \alpha_t t + \frac{1}{2}\sum_m \sum_n \beta_{mn} \ln x_{mit} \ln x_{nit} + \frac{1}{2}\beta_{tt} t^2 + \sum_m \beta_{tm} \ln x_{mit} * t + v_{it} - u_{it} \qquad (4)$$

m , *n* = *D*(land), *L*(labor), *F*(fertilizer) and *P*(power).

Labor, fertilizer and power are the same inputs used in the construction of Malmquist index.

Equation (4) is estimated using Coelli’s Frontier 4.1 econometric package with symmetry imposed. The maximum likelihood estimates of the parameters are included in the Appendix.

Technical change is obtained through differentiation of equation (4) with respect to *t:*

$$\frac{\partial \ln Y_{it}}{\partial t} = \alpha_t + \beta_{tt} t + \sum_m \beta_{tm} \ln x_{mit} \tag{5}$$

Technical efficiency level of firm *i* at time *t* is defined as follows.

$$TE_{it} = \exp(-u_{it}) \tag{6}$$

It is the ratio of the actual output to the potential output.

The elasticity of output with respect to the *mth* input, the production elasticity of input *m*, is defined by

$$\varepsilon_m = \frac{\partial \ln Y_{it}}{\partial \ln x_m} = \alpha_m + \sum_{n \neq m} \beta_{mn} \ln x_n + \beta_{mm} \ln x_m + \beta_{tm} * t, \tag{7}$$

m, n=D, L, F and *P*.

Using these production elasticities we can obtain an estimate of aggregate returns to scale, $\varepsilon = \sum_m \varepsilon_m$. When *RTS>1, =1* and *<1,* there are increasing, constant and decreasing return to scale respectively.

The rate of TFP (total factor productivity) is defined as the rate of change in output that is not explained by the input change:

$$T\dot{F}P = \dot{y} - \sum_m \varepsilon_m \dot{x}_m = \textit{Technical change} + \textit{Efficiency change}. \tag{8}$$

The national and provincial average rates of technical change and efficiency change along with the rates of change of TFP from 1993 to 2005 are reported in table 3 and table 4 respectively. This method results in a positive rate of technical change and a negative rate of efficiency change throughout the period. The interaction of both forces yields a positive trend of TFP up until 1998 and a reversal thereafter. The mean rate of TFP change is estimated at 0.17%. The combination of the linear trend imposed to capture technical change plus the reversal of the trend in 1998 results in an estimated rate of change of TFP close to zero. Although this seems, at first glance, inconsistent with the Malmquist results, we remind the reader that the econometric method imposes a smooth trend to technical change as it uses a time trend to capture it. In addition, the econometric estimates are a result of using the complete data set while the Malmquist only uses two consecutive years at a time. As a result the Malmquist exacerbates yearly changes while the stochastic production frontier smoothes out the yearly changes and given the trend impose, it has strong inertia built in which makes a reversal in trend very difficult if not impossible. More on this issue in a later section when we discuss the effects on the econometrics of partitioning the data set in 1998, the year where there is a trend reversal.

From Table 4 we conclude that 12 out of 29 provinces experienced average positive TFP growth. Qinghai, Beijing and Tianjin define the frontier and its shift throughout the period. The worst performer is Henan.

In depth analysis requires that we look at the evolution of the estimates for each province through the period. Detailed information for all provinces and all years is provided in Appendices 4 and 6.

A summary of the information in these tables is presented in Figure 5 where the evolution of the rate of TFP is shown aggregated into three regions. This graph shows a clear downward trend (the linearity has been imposed by the approximation chosen) and shows that the West has consistently outperformed the Central and East regions (see also Appendix 5). This is not consistent with results from the Malmquist Index approach where the East region outperformed the other two during most of the period under analysis. In addition, this method does not show the reversal of the trend estimated by the

Malmquist index, showing the inertia imposed by the technical change proxy used that precludes a trend reversal.

VI. Critical Analysis of Methodologies Used.

In order to compare results from such disparate methods we first add Table 1b. This table smoothes out the results from the contemporaneous Malmquist index by obtaining a five year moving average of the yearly estimates. This is a rather crude attempt at making results from an index that uses only information from consecutive years more comparable with results from the econometric method that uses information for the whole period showing strong inertia in the results.

Comparing tables 1a, 1b, and 3 we see that smoothing out the Malmquist index decreases the variability of the index showing a u-shape behavior, with an estimated smaller rate of TFP change which turns negative in the first half of the period and then reverts becoming positive again in the 2000's. As we smooth out the index we see a change from an average positive rate in the contemporaneous Malmquist to a negative average rate for the moving average Malmquist to a slightly negative one for the econometric estimation that includes a time trend. It is worth noticing that technical change is estimated as positive by all three methods. All three methods also estimate, on average, negative efficiency change throughout the period of analysis. A comparison of interest is the one presented in Figure 6 where the average rates of agricultural productivity growth estimated by all three methods are displayed.

It is easily seen that the SPF approach yields a slight negative trend of TFP throughout the period while the contemporaneous Malmquist and the 5 year moving average Malmquist show a negative trend up until late 1990's becoming positive afterwards. Once again this confirms the biases imposed by each of the methods, although all of them indicate a decline until the late 1990's, the Malmquist indexes show a recovery in the 2000's while the SPF is unable to revert the trend given the linearity imposed by the second order approximation used.

During the period of study agricultural output had a sinusoidal behavior as seen in Figure 2. It grew from 1993 to 1997, slightly decreasing from 1997 to 1999, staying at a constant level from 1999 until 2002, then increasing again till 2005. Even though output did not show a substantial decrease in this period the Malmquist index estimates show a worsening in TFP growth performance until 1998. This is probably due to a very high rate of increase in the use of two inputs: fertilizer and power. This is not a surprise and is common in most analysis of productivity in agriculture as the sector phases into heavy use of modern inputs with the introduction of modern agricultural practices and biotechnology ('biotech revolution' technology). This parallels the issues encountered in the past by others when estimating agricultural productivity growth in countries that adopted green revolution technologies increasing the use of modern inputs much faster than output. Even though the share of modern inputs might still be smaller than that of traditional inputs like land, their rapid rate of increase drowns the increases in output. This is one of the reasons studies have measured agricultural productivity declines in countries that adopted modern techniques. It is a reflection of the limitations of the methods used in estimation.

Second, we have noted before that while the Malmquist method show a reversal of the trend of TFP in the 2000's (from negative to posititve), the SPF approach does not. To continue the critical analysis of results provided by these two very different methods, we present a summary of the estimations performed by Tong and Fulginiti when the time series covered a shorter period, 1993-2001. As can be seen in Figure 7 the econometric trend and the Malmquist index are consistently capturing the evolution of TFP change within the constraints imposed by each method. Given that we did not have data for the 2002-2005 period of positive rates, the econometric trend estimated then shows TFP rates declining at a faster rate than in the updated estimates of this paper. As TFP rates increased in the later years, the new estimate of this trend shows TFP rates declining but at the much slower rate. This is the way the linear trend 'captures' the reversal in this trend.

Third, to continue the critical analysis of the methods used, an additional set of estimations is performed by dividing the data in two sub-periods. The first one includes the sub-period 1994-1998 and the second, the sub-period 1999-2005. The values of technical change, efficiency change and TFP change are reported in tables 3a and 3b. The first sub-period (1994-1998) displays positive values of TFP change and their components. This table also shows that TFP grows at a decreasing rate. The second sub-period (1999-2005) as reported by table 3b displays negative values of TFP change and their components but the decrease in TFP occurs at a decreasing rate.

Figure 8 superimposes results of these SPF estimations with the estimates from the Malmquist index and the SPF for the whole period. The econometric estimation shows a negative rate of TFP growth for the period 1994-1998 and a positive rate of TFP growth for the period 1999-2005. So when trends do not have an inflexion point, the approximation used here performs relatively well. It clearly illustrates that the second order specification used here, which yields a first order or linear approximation to TFP growth, is unable to capture trend reversals in the derivatives.[10] In these situations the trend estimated collapses to an almost horizontal line with a slope of 0.

VII. Comparative Analysis.

The estimates in this paper are reproduced in Table 5 with the purpose of comparing them with relevant studies. We proceed with a comparison even though it is clear from this table that only a few others cover the 2000's and provide provincial estimates, not all use the same methodology, and data sources are disparate. As shown in Figures 2 and 3, there are important differences in evolution of the data from the two main sources used in the literature, FAO and CSY.

First, it is interesting to note that our SPF estimates are not, at first sight, consistent with those obtained by Tong and Fulginiti (2003) covering the period 1993-2001. In fact the latter displays a higher positive average for the country during the period of study (0.4%) while in this study this average is much lower (0.17%). As explained in the section above this is perfectly consistent given the trend reversal in the 2000's that when using a linear trend is captured by a decrease in the slope of this line. Regarding the results obtained with the Malmquist approach, Tong and Fulginiti's earlier results are consistent with those of this study during the period 1994-2001. This consistency does not come as a surprise since both studies use the same methodology and data source but for this study extends the period of analysis to 2005.

Moreover, during the period 1994-1998, the results estimated by the SPF approach

[10] This is a point emphasized by those proposing global instead of local second order approximations as for example a Fourier approximation instead of a second order Taylor approximation.

are consistent with those of Lambert et al. (1998), Colby et al. (2000), Wu et al. (2001), Fan et al. (2002), Lezin et al. (2005), Hsu et al. (2003), and Dekle et al (2006). The differences between results in this study and those of Jin et al. (2002) and Meade (2003) are not surprising considering the many differences between them in terms of data, periods and sectors covered. Jin et al. (2002) used data collected by the State Price Bureau. They calculated provincial and national TFP indices based on a sampling framework with more than 20,000 households producing three major crops: wheat, rice and maize. Meade (2003), on the other hand, uses a time series of provincial data from Chinese Statistical Yearbook, Chinese Rural Statistical Yearbook, and Chinese Agricultural Yearbooks to fit a two-way fixed effects constant-returns-to scale Cobb-Douglas production function for Chinese agriculture and then calculates TFP residually. This study uses as "output" an aggregate of 22 activities listed in their paper.

There are three studies that analyze Chinese agricultural productivity covering most of the years in the second sub-period. These are Dekle et al. (2006), Bosworth et al. (2008), and Nin Pratt et al. (2009). Bosworth et al. estimated agricultural TFP growth as a residual based on a constant-returns-to-scale Cobb Douglas approximation to the technology. The estimation was based on data on the Chinese primary sector from the Chinese Statistical Yearbook. They do not show yearly productivity growth estimates, but only a period average. They report a positive average rate of TFP growth which is consistent with our results.

Dekle et al. report positive annual values of agricultural TFP growth up to 2003. These values are close to those of the Malmquist index calculated in this study. They base their estimations on provincial time series data from the Chinese Statistical Yearbook

(CSY) as we do. They follow Young's methodology by deflating the nominal GDP reported in the CSY not by the GDP deflator as we do but by other survey based price indices.[11] There are also important methodological differences with our study. Just as Bosworth et al., Dekle et al. calculate TFP growth as a residual based on a constant-returns-to-scale Cobb Douglas production function.

Results from multi-country studies discussed in the literature review, report average values of Chinese agricultural productivity change for periods significantly longer than ours and are, as such, not directly comparable to ours. Therefore results for other than the Nin Pratt et al. study were not included in Table 5. Nin Pratt et al. study, even though of a multi-country nature is given special attention because it focused on China and it is one of the most recent in the literature. They report a figure with annual values of agricultural TFP growth rates for China based on Tornquist-Theil and Malmquist Indices. The Tornquist-Theil index yields positive yearly rates of TFP growth during the period 1994-1996 and a negative rate in 1997. As a result, agricultural TFP grew, in average, 2.97% per year during the period 1994-1997. The Malmquist index, also shows strong positive growth rates of TFP in Chinese agriculture for the period 1994-2003, except for 1999. The estimates in Nin Pratt et al. were calculated using FAO data covering the period 1967-2003 for 59 countries including China and India. They use two aggregate outputs (crops and livestock production) and seven inputs (land, labor, tractors, fertilizers, area under irrigation, feed and animal stock).

VIII. A Model for Differential Performance of the Regions.

In an attempt to identify variables that are potential contributors to technical

[11] General price index of farm products, ex-factory industrial price index, and service price index.

inefficiency, we follow the specification of Battese and Coelli (1995). They suggest that technical inefficiency, which reflects regional heterogeneity, may be influenced by particular variables. In our case we hypothesize that differential performance of the regions will be affected by availability of public goods like public agricultural expenditures, education, and infrastructure.

The model is specified as follows:

$$\ln Y_{it} = \alpha_0 + \sum_m \alpha_m \ln x_{mit} + \alpha_t t + \frac{1}{2}\sum_m \sum_n \beta_{mn} \ln x_{mit} \ln x_{nit} + \frac{1}{2}\beta_{tt} t^2 + \sum_m \beta_{tm} \ln x_{mit} * t + v_{it} - u_{it} \qquad (9)$$

Y_{it} , x_{it} and β are the same as defined earlier.

V_{it} are still assumed to be random errors which are iid N (0 $\sigma_V{}^2$) and are independent of U_{it}. U_{it} are non negative random variables that account for technical inefficiency. U_{it} are independently distributed as truncations at zero of the N (m_{it} , $\sigma_U{}^2$). And $m_{it} = z_{it}\delta$. Here z_{it} is a *3*1* vector of variables that may contribute to the technical efficiency of a region. And δ is the parameter vector to be estimated.

The three variables in the *z* vector are: public agricultural expenditures, the rate of illiteracy, and the irrigation ratio. We expect that the first and the third will increase technical efficiency, and the second will lower technical efficiency.

Public agricultural expenditures include expenditures on agricultural water conservancy, meteorology, resource investigation, subsidies to well drilling, sprinkling irrigation projects and popularization of improved varieties. The amount of expenditure is related to the production level. To get a unit level expenditure, total agricultural expenditure of each province is divided by total sown area in each province. This can be viewed as a provision of a public goods to farmers and we should expect it to contribute positively to productivity.

The rate of illiteracy includes illiterate and semi-literate population ratio for individuals of age 15 and over. This variable can be viewed as a proxy for education, which reflects the quality of the labor input. We expect a negative sign here.

Irrigation denotes the irrigation ratio, which states the ratio of irrigated area to total sown area. This can be viewed as a proxy for land quality and a positive sign is expected.

The estimated regression is based on a shorter data set including data from 1996 to 1999 and 2001 due to lack of information on some of the variables[12]. The impact of these variables in explaining differential behavior across regions is reported in table 6. It should be noted that this is not a special case of the model of the last section. In fact these models are non-nested and we use fewer observations in the latest estimation. So we will not compare the estimated coefficients from the two specifications. Table 6 only reports the estimates of the parameter of the *z* vector of variables to give us some idea of the impact of these variables. This analysis indicates that availability of public goods like R&D, education and infrastructure are important in explaining the differential performance of the agricultural sector across Chinese provinces. These figures indicate that the more human capital, infrastructure, and research expenditures the better the performance of the region.

IX. Conclusion

In this paper a nonstochastic Malmquist index and a stochastic frontier production function are estimated to examine agricultural productivity growth in Chinese provinces

[12] Year 2000 is excluded because the yearbook for that year's data does not provide the illiterate ratio we used for our model.

during the period 1994-2005. Results indicate productivity growth declining in the mid 1990's, a trend reversal starting in 1998, and growth rates increasing for the rest of the period. While the Malmquist index picks up a reversal of this trend in 1998-1999, the stochastic frontier estimates based on a second approximation to the production function is, by construction, unable to pick up this reversal. As a consequence the econometric estimates show a stagnant rate of TFP growth. We show that while the year to year Malmquist index is very sensitive to outliers and only uses information from two consecutive years, the second order Taylor approximation to the production function used in the econometric approach severely constrains the estimate of the TFP growth rates to a linear trend. Critical comparison of the two approaches is necessary to understand the evolution of productivity growth in Chinese agriculture. Conclusions based on comparison of average results across methods is unreliable. One should also be very careful when comparison is done across studies because they have used different methodologies, different data sources, and have covered different years. The estimates in this study provide a contrast with estimates based on FAO statistics used by the majority of other studies as opposed to data obtained directly from the Chinese Statistical Yearbooks; with estimates that only used one approach; and with estimates for the country as a whole versus those derived from provincial information. We do show national estimates but these are obtained from aggregation of provincial estimates and as such provide less information than the more local estimates. TFP growth estimates for each province, except Tibet, and for each year are obtained with two radically different methods. They provide information about the differential performance of the different regions, showing higher rates of TFP growth in the East. Additionally, variables representing public inputs such as education, research and infrastructure are shown to have an important impact on differential regional performance.

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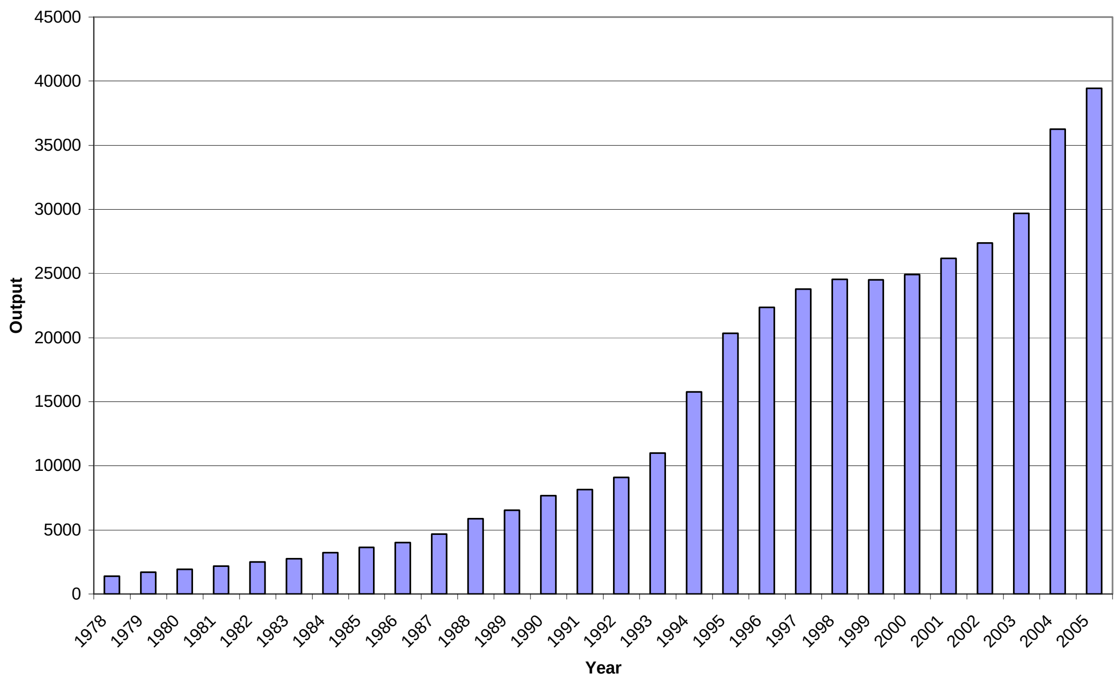
Figures

Figure 1: Gross Output Value of Agriculture (1978-2005)



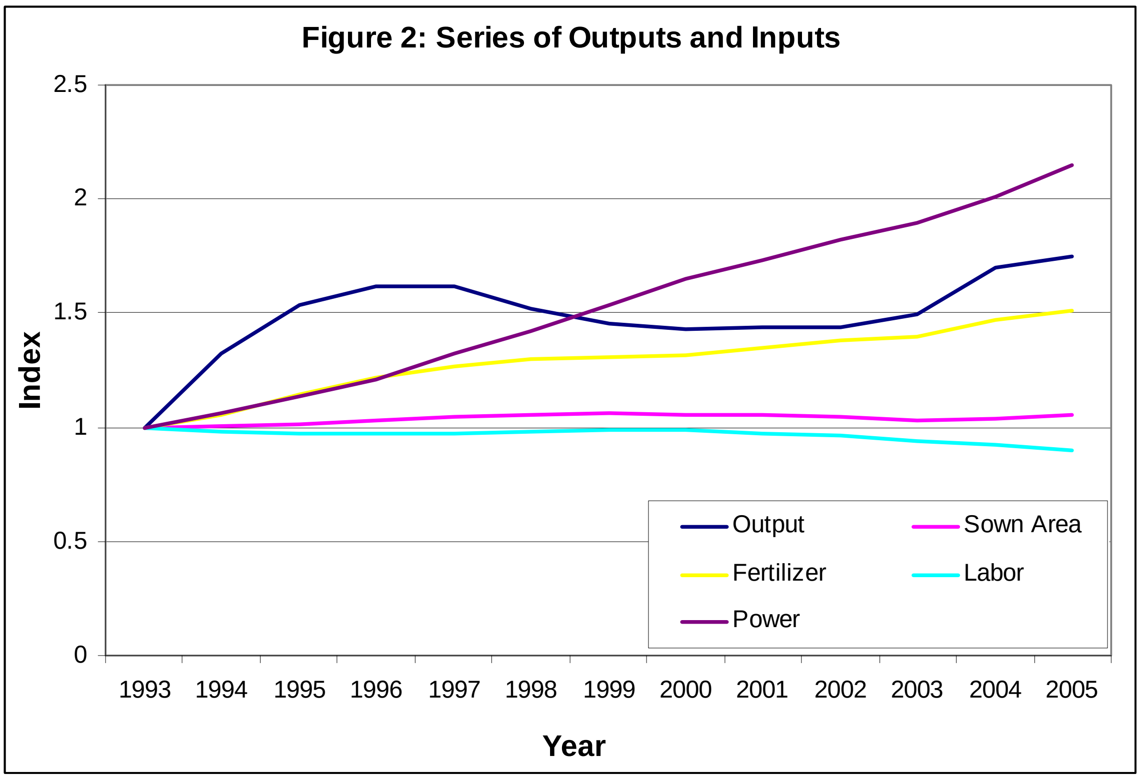


Figure 3: Series of Outputs and Inputs (FAO)

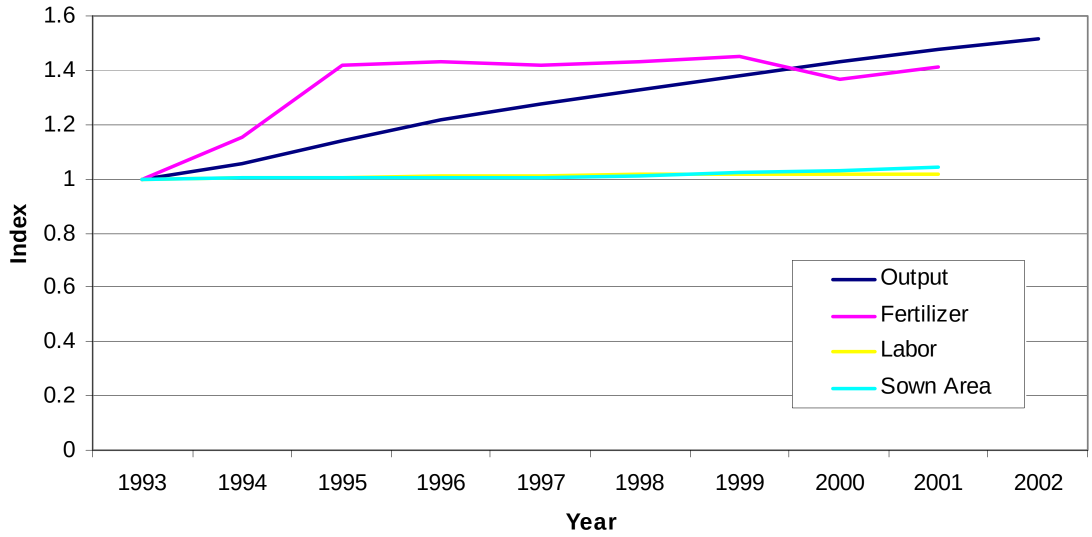


Figure 4: Annual average TFP change rate (%) of each area (Malmquist index method)

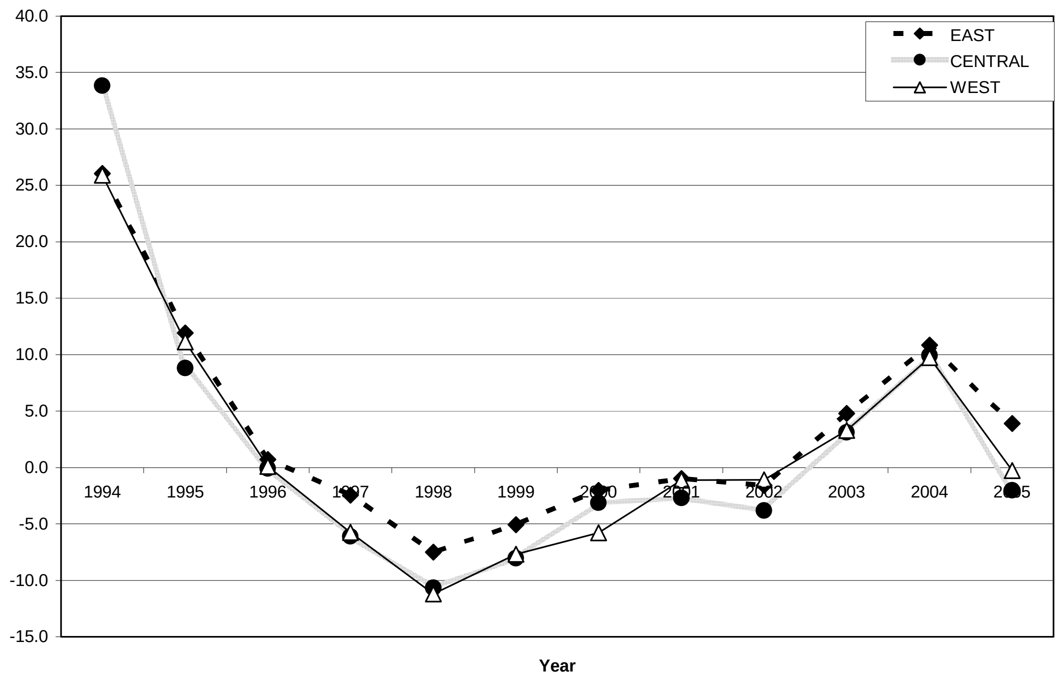


Figure 5: Annual Average TFP Change Rate (%) of Each Area (Stochastic Frontier)

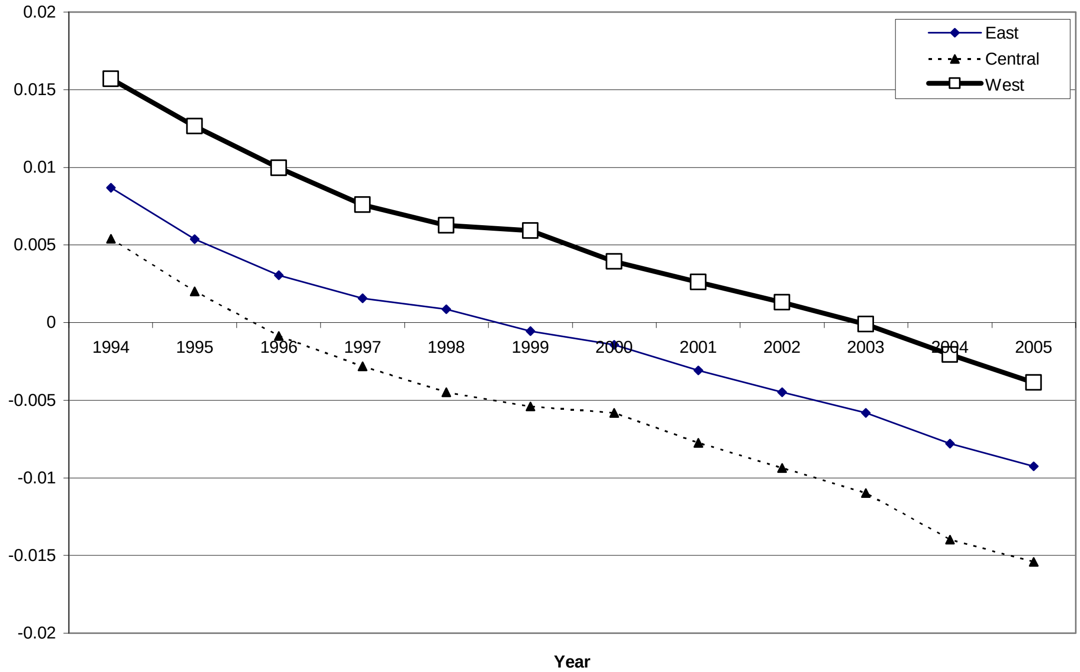


Figure 6: Comparison of Rate of TFP Change (%)

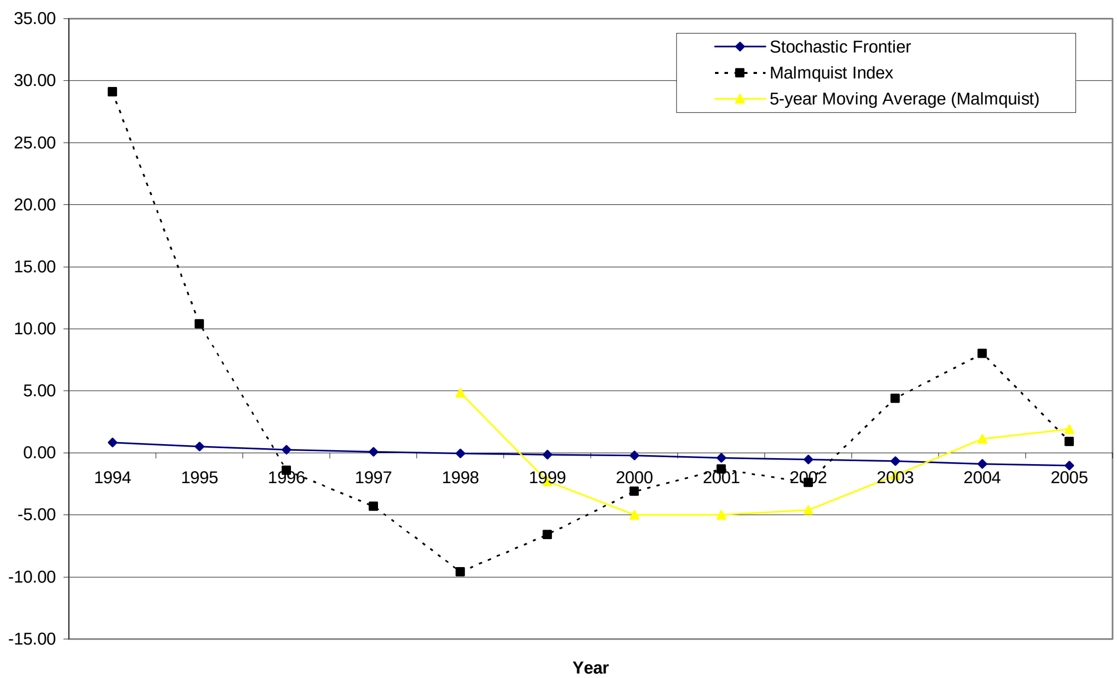


Figure 7. Comparison of Rate of TFP Change (%) 1993-2001

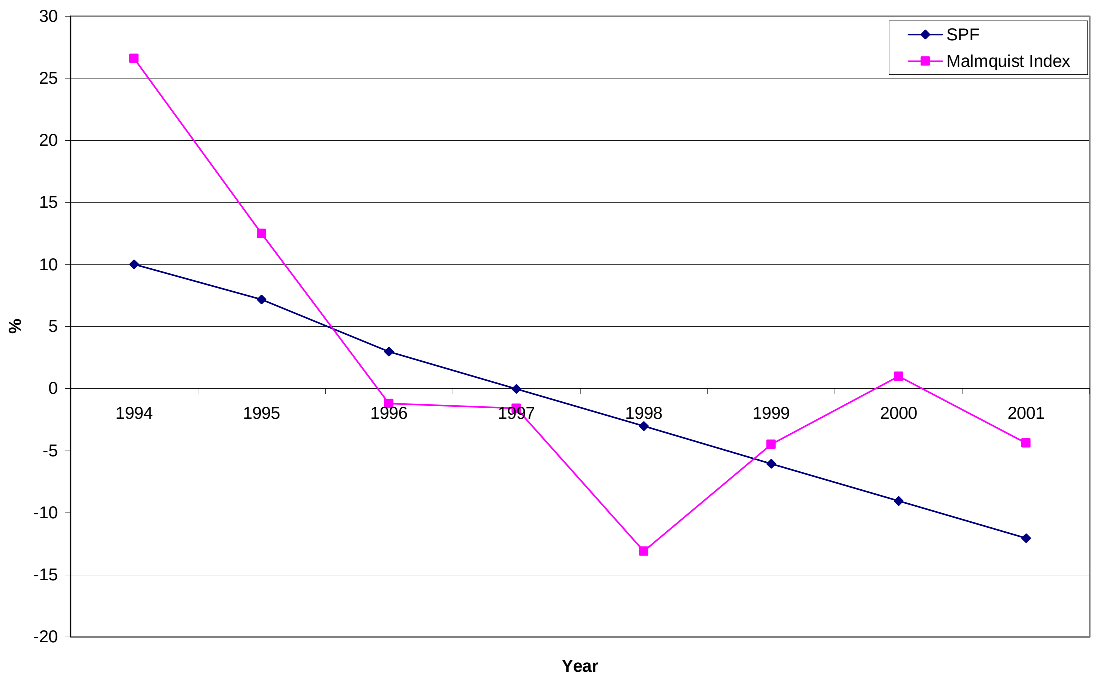
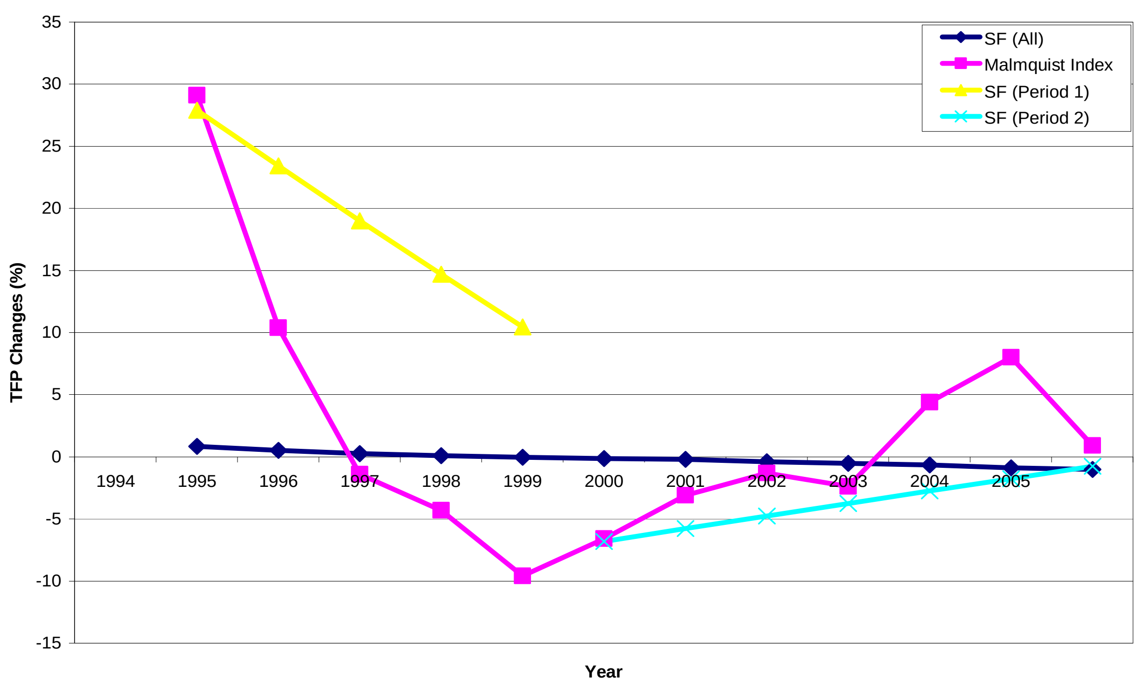


Figure 8: Comparison of TFP Change (%) for All Methods



Tables

TABLE 1a. MALMQUIST INDEX SUMMARY OF ANNUAL MEANS			
year	effch	techch	tfpch
1994	1.051	1.228	1.291
1995	1.061	1.04	1.104
1996	0.965	1.022	0.986
1997	0.879	1.089	0.957
1998	0.937	0.965	0.904
1999	1.041	0.897	0.934
2000	0.955	1.015	0.969
2001	0.961	1.027	0.987
2002	0.922	1.059	0.976
2003	0.91	1.147	1.044
2004	0.99	1.091	1.08
2005	0.913	1.105	1.009
MEAN	0.964	1.054	1.016

TABLE 1b. MALMQUIST INDEX SUMMARY OF ANNUAL MEANS (5 year moving average)			
year	effch	techch	tfpch
1998	0.9786	1.0688	1.0484
1999	0.9766	1.0026	0.977
2000	0.9554	0.9976	0.95
2001	0.9546	0.9986	0.9502
2002	0.9632	0.9926	0.954
2003	0.9578	1.029	0.982
2004	0.9476	1.0678	1.0112
2005	0.9392	1.0858	1.0192
MEAN	0.9591	1.0303	0.9865

Table 2. MALMQUIST INDEX SUMMARY OF PROVINCIAL MEANS

REGION	effch	techch	tfpch
Beijing	1.000	1.063	1.063
Tianjing	0.949	1.036	0.983
Hebei	0.978	1.056	1.033
Shanxi	0.992	1.039	1.030
Inner Mon.	0.950	1.035	0.983
Liaoning	0.961	1.065	1.024
Jilin	0.953	1.069	1.018
Heilongjiang	0.944	1.055	0.996
Shanghai	1.000	1.079	1.079
Jiangsu	0.963	1.087	1.047
Zhejiang	0.990	1.049	1.038
Anhui	0.957	1.049	1.004
Fujian	0.964	1.076	1.038
Jiangxi	0.950	1.059	1.006
Shandong	0.961	1.064	1.022
Henan	0.956	1.062	1.015
Hubei	0.945	1.070	1.011
Hunan	0.980	1.035	1.015
Guangdong	0.962	1.059	1.019
Guangxi	0.939	1.051	0.987
Hainan	0.939	1.039	0.975
Sichuan	0.957	1.060	1.015
Guizhou	0.953	1.055	1.006
Yunnan	0.967	1.032	0.998
Shaanxi	0.944	1.061	1.002
Gansu	0.974	1.031	1.004
Qinghai	1.019	1.031	1.050
Ningxia	0.952	1.044	0.993
Xinjiang	0.956	1.055	1.009
MEAN	0.964	1.054	1.016

Table 3			
Stochastic Frontier Summary of Annual Means			
Year	Rate of Technical Change	Rate of Technical Efficiency Change	Rate of TFP change
1994	0.018	-0.010	0.008
1995	0.015	-0.010	0.005
1996	0.013	-0.010	0.003
1997	0.011	-0.010	0.001
1998	0.010	-0.010	0.000
1999	0.009	-0.011	-0.001
2000	0.009	-0.011	-0.002
2001	0.007	-0.011	-0.004
2002	0.006	-0.011	-0.005
2003	0.005	-0.011	-0.007
2004	0.002	-0.011	-0.009
2005	0.001	-0.011	-0.010
MEAN	0.009	-0.010	-0.0017

Table 3a			
Stochastic Frontier Summary of Annual Means			
Year	Rate of Technical Change	Rate of Technical Efficiency Change	Rate of TFP change
1994	0.274	0.005	0.279
1995	0.230	0.005	0.234
1996	0.185	0.005	0.190
1997	0.142	0.005	0.147
1998	0.100	0.005	0.104

Table 3 b			
Stochastic Frontier Summary of Annual Means			
Year	Rate of Technical Change	Rate of Technical Efficiency Change	Rate of TFP change
1999	-0.064	-0.00376	-0.068
2000	-0.054	-0.00375	-0.058
2001	-0.044	-0.00379	-0.048
2002	-0.034	-0.00378	-0.038
2003	-0.024	-0.00382	-0.027
2004	-0.014	-0.00383	-0.018
2005	-0.004	-0.00382	-0.008

Table 4			
Stochastic Frontier Summary of Regional Means			
Region	Technology change rate	Technical Efficiency Change Rate	TFP change rate
Beijing	0.060	-0.011	0.049
Tianjin	0.066	-0.020	0.046
Hebei	0.004	-0.013	-0.009
Shanxi	0.028	-0.020	0.008
Inner Mongolia	0.032	-0.014	0.018
Liaoning	0.018	-0.008	0.009
Jilin	0.016	-0.018	-0.003
Heilongjiang	0.020	-0.015	0.004
Shanghai	0.053	-0.013	0.040
Jiangsu	-0.008	-0.012	-0.020
Zhejiang	0.026	-0.001	0.024
Anhui	0.001	-0.013	-0.012
Fujian	0.013	-0.007	0.006
Jiangxi	0.017	-0.010	0.007
Shandong	-0.009	-0.012	-0.021
Henan	-0.009	-0.014	-0.023
Hubei	-0.004	-0.016	-0.020
Hunan	0.009	-0.005	0.004
Guangdong	0.005	-0.001	0.004
Guangxi	0.010	-0.012	-0.002
Hainan	0.048	-0.016	0.032
Sichuan	-0.001	-0.001	-0.002
Geizhou	0.030	-0.011	0.018
Yunnan	0.020	-0.010	0.011
Shaanxi	0.013	-0.017	-0.004
Gansu	0.035	-0.018	0.016
Qingghai	0.087	-0.034	0.053
Ningxia	0.054	-0.036	0.019
Xinjiang	0.024	-0.018	0.006

Table 5. Annual Percentage Changes in Agricultural TFP in China														
Author	Method	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Avg.
Tong, Fulginiti, and Sesmero	SPF	0.8	0.5	0.3	0.1	0	-0.1	-0.2	-0.4	-0.5	-0.7	-0.9	-1	-0.18
	SPF (2 sub-periods)	0.28	0.23	0.19	0.15	0.10	-0.07	-0.06	-0.05	-0.04	-0.03	-0.02	-0.01	0.06
	DEA-Malmquist	29.1	10.4	-1.4	-4.3	-9.6	-6.6	-3.1	-1.3	-2.4	4.4	8.00	0.9	2.01
	DEA-Malmquist (5 Year Moving Average)					4.84	-2.3	-5.00	-4.98	-4.60	-1.80	1.12	1.92	-1.35
Tong, and Fulginiti (2003)	SPF	1.27	1.12	0.99	0.98	0.87	0.95	1.01	0.96					1.01
	DEA-Malmquist	0.1	0.07	0.03	-0.0002	-0.03	-0.06	-0.09	-0.12					0.004
Wu et al. (2001)	DEA-Malmquist	3.95	0.64											2.3
Fan et al. (2002)	Accounting (Tornquist-Teil)	5.96	6.47	4.73	0.25									4.35
Jin et al. (2002)	Accounting (Tornquist-Teil)	-6.32	0											-3.16
Mead (2003)	Prod Funct (CD)	2.06	-0.47	-1.03										0.19
Lezin et al. (2005)	Review	1.72	1.94	-0.22	1.58									1.26
Deckle et al. (2006)	Prod Funct (CD)	9.1	4.16	16	6.9	3.22	12.5	8.9	2.04	2	0.98			6.58
Nin Pratt et al. (2009)	DEA-Malmquist	5.88	2.78	8.11	2.50	4.88	-2.33	7.14	4.89	5.93	4.42			4.90
	Accounting (Tornquist-Theil)	3.55	3.43	3.73	6	-1.88								2.97
Lambert et al. (1998)	Accounting-Divisa	1993-1995												5.8
Colby et al. (2000)	Accounting-Divisa	1995-1997												0.8
Hsu et al. (2003)	DEA-Malmquist	1993-2000												1
Bosworth et al. (2008)	Prod Funct (CD)	1993-2004												1.7

Table 6. Estimates of the Parameters of the z Vector				
		Coefficients	Standard-error	t-ratio
Irrigation	delta 1	-0.0110	0.0047	-2.35
Illiterate	delta 2	0.0208	0.0046	4.53
Ag expenditure	delta 3	-0.0054	0.0008	-6.83

Appendix 1. Data Summary Across Regions										
	Gross Output Value*		Land Area**		Fertilizer		Labor		Power	
	(100 Million Yuan)		(1000 hectares)		(10000 tons)		(10000 persons)		(10000 kw)	
	Mean	STDV	Mean	STDV	Mean	STDV	Mean	STDV	Mean	STDV
1993	367	279	4925	3489	105	89	1109	975	1061	860
1994	484	359	4941	3495	111	90	1090	952	1127	953
1995	564	412	4996	3523	120	98	1078	939	1204	1055
1996	594	436	5079	3569	128	105	1075	928	1285	1193
1997	593	437	5132	3598	133	108	1081	924	1403	1368
1998	558	411	5190	3655	136	113	1088	917	1507	1493
1999	534	393	5212	3671	137	115	1097	936	1633	1657
2000	523	385	5210	3709	138	117	1093	945	1752	1818
2001	527	390	5190	3733	142	121	1082	927	1839	1930
2002	526	391	5155	3731	145	123	1066	902	1931	2032
2003	549	405	5080	3727	147	124	1042	876	2013	2108
2004	623	470	5118	3743	155	127	1020	854	2134	2229
2005	642	485	5183	3784	159	132	999	829	2280	2333

Note: * Gross output value is deflated by indices of gross output.
**Land area is total sown area.

Appendix 2

Estimated coefficients: Translog Approximation				
	Parameters	coefficient	standard-error	t-ratio
Intercept	α_0	-3.8796	3.5827	-1.0829
log(land)	α_D	3.0786	1.4597	2.1091
log(labor)	α_L	-0.6587	0.7992	-0.8242
log(fertilizer)	α_F	-1.5717	0.9577	-1.6411
log(power)	α_P	0.4834	0.7299	0.6622
time	α_t	0.0934	0.0466	2.0032
log(land)^2	β_{DD}	-0.1636	0.2196	-0.7448
log(labor)^2	β_{LL}	-0.0778	0.0919	-0.8471
log(fertilizer)^2	β_{FF}	0.2042	0.1319	1.5486
log(power)^2	β_{PP}	0.0524	0.0659	0.7951
log(land)*log(labor)	β_{DL}	0.1701	0.2134	0.7973
log(land)*log(fertilizer)	β_{DF}	0.2015	0.2615	0.7705
log(land)*log(power)	β_{DP}	-0.3069	0.2529	-1.2135
log(labor)*log(fertilizer)	β_{LF}	-0.2304	0.1660	-1.3883
log(labor)*log(power)	β_{LP}	0.1455	0.1605	0.9066
log(fertilizer)*log(power)	β_{FP}	0.0640	0.1223	0.5234
log(land)*time	β_{Dt}	0.0043	0.0152	0.2820
log(labor)*time	β_{Lt}	0.0004	0.0105	0.0377
log(fertilizer)*time	β_{Ft}	-0.0317	0.0117	-2.7215
log(power)*time	β_{Pt}	0.0061	0.0089	0.6798
time^2	β_{tt}	-0.0010	0.0006	-1.5094

Appendix 3. Summary of Provincial Efficiency Change Rate, Technical Change Rate and TFP Change Rate (Malmquist Index)

Summary of Provincial Efficiency Change Rate (%) (Malmquist Index)												
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Beijing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tianjing	0.0	0.0	-8.1	-24.8	-1.5	6.7	-4.8	-12.9	-8.1	0.2	-5.2	1.2
Hebei	2.5	17.2	-10.0	-9.1	-3.0	8.5	-3.6	-10.7	-7.6	-4.7	12.2	-12.7
Shanxi	8.1	20.2	1.1	-23.4	6.2	11.4	-2.9	-6.2	-8.5	-2.7	5.3	-11.0
Inner mongolia	20.5	-2.1	-6.4	-32.4	15.8	13.7	2.6	-10.3	-9.1	-14.6	-6.1	-18.2
Liaoning	-3.4	8.0	-6.5	-12.0	-8.4	8.3	1.8	0.5	-8.2	-14.4	1.1	-10.1
Jilin	25.0	1.2	-13.8	-2.5	-11.0	-6.4	-7.5	2.3	-16.4	-6.0	-3.4	-12.1
Heilongjiang	0.2	10.6	-1.1	-26.9	-17.2	10.1	-2.1	4.4	-10.4	0.7	-14.9	-12.5
Shanghai	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jiangsu	2.3	-5.6	-8.9	1.2	-2.3	-4.2	-8.7	-3.9	-4.2	-11.1	4.4	-2.0
Zhejiang	5.3	-0.7	1.7	-19.5	15.6	11.3	5.3	-9.1	-3.8	-7.9	2.7	-8.0
Anhui	11.6	-0.1	-11.2	-10.0	-12.4	11.2	-3.8	-8.4	-5.3	-11.4	6.3	-13.7
Fujian	-2.7	-2.3	-8.9	-0.2	-5.2	-0.8	-3.3	-3.8	-2.7	-10.2	-2.8	0.1
Jiangxi	10.8	9.2	-5.3	-3.5	-11.0	-9.9	-2.3	1.6	-10.9	-14.1	-6.8	-13.4
Shandong	-7.7	6.7	2.4	-7.2	-12.7	-5.6	-6.2	-5.3	-5.1	-3.1	3.7	-5.2
Henan	-3.2	6.8	3.0	-19.0	-2.3	7.1	-7.3	-6.1	-12.0	-11.4	5.2	-9.9
Hubei	18.9	5.2	-4.3	-0.2	-13.2	-8.9	-11.9	-6.7	-9.4	-15.9	-3.1	-11.9
Hunan	10.7	7.9	2.4	-8.2	-17.0	10.2	1.5	-1.1	-7.3	-9.8	4.5	-12.8
Guangdong	-8.7	2.2	2.3	-8.6	-6.5	11.4	-9.2	-7.0	-8.4	-11.1	-2.1	3.3
Guangxi	0.7	9.7	1.3	-5.4	-22.3	-8.2	-5.0	-2.1	-14.8	-11.3	-1.4	-10.2
Hainan	0.0	0.0	0.0	-9.7	-8.5	21.1	-22.4	-6.5	-9.2	-24.3	-7.5	1.5
Sichuan	7.2	6.5	-5.0	0.2	-13.8	-12.1	-8.5	6.2	-6.7	-10.9	0.1	-11.4
Guizhou	10.5	13.2	-9.2	0.5	-12.9	-9.0	-9.8	5.1	-12.6	-13.8	-1.2	-12.1
Yunnan	-1.8	13.7	7.4	-17.7	-4.1	38.7	-15.7	-6.2	-10.5	-14.9	-3.9	-11.8
Shaanxi	2.6	13.2	-4.7	-5.1	-11.8	-11.7	-6.3	4.8	-9.2	-22.1	-1.9	-9.9
Gansu	21.0	20.4	-4.1	-30.1	0.3	13.2	-1.7	-8.1	-10.7	-8.4	2.4	-13.5
Qinghai	20.8	8.0	4.4	-23.3	13.9	16.3	-0.8	-7.6	-3.7	3.1	7.9	-8.3
Ningxia	8.0	6.6	-3.0	-27.8	-19.3	12.9	13.4	-6.5	-7.1	-7.0	-4.6	-14.3
Xinjiang	-1.2	6.7	-11.6	-7.9	-4.7	1.8	-5.2	-6.5	-2.8	4.2	-14.2	-8.8

Summary of Provincial TFP Change Rate (%) (Malmquist Index)												
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Beijing	25.7	16.6	3.9	1.6	-2.1	-3.2	1.3	12.3	6.1	11.3	4.1	1.6
Tianjing	14.1	0.8	-12.2	-5.4	-8.0	-8.6	-5.9	0.0	-4.6	10.3	-1.6	3.9
Hebei	26.9	27.5	-9.4	2.3	-5.4	-3.0	-4.7	2.6	-4.1	4.9	11.0	-1.7
Shanxi	28.3	24.2	-2.6	0.6	-8.6	-6.9	-4.8	1.9	-4.7	8.2	7.1	0.1
Inner mongolia	39.0	-1.8	-11.0	-11.3	-0.3	-5.7	0.1	-4.6	-4.5	-3.8	-0.5	-8.0
Liaoning	28.7	11.6	-4.9	-0.8	-9.5	-4.1	3.7	0.8	-1.8	-1.9	10.3	1.2
Jilin	52.4	5.5	-5.8	-6.9	-9.9	-7.1	-2.5	-1.1	-10.8	10.1	13.1	-1.3
Heilongjiang	34.1	13.3	1.9	-11.8	-22.5	-13.0	-2.4	5.6	-4.3	15.3	-7.4	-1.5
Shanghai	38.6	10.6	5.7	11.3	-6.6	-12.4	6.3	-0.7	5.2	18.7	16.0	10.5
Jiangsu	35.0	8.3	-2.4	-2.4	-3.4	-5.8	-2.8	1.8	-1.2	4.2	22.2	9.8
Zhejiang	30.0	6.5	0.9	1.6	2.1	-6.5	3.8	0.9	-0.3	1.9	4.6	3.6
Anhui	37.2	3.7	-7.6	-6.2	-12.4	-6.2	-2.8	-9.2	1.7	2.0	16.5	-2.9
Fujian	25.7	10.1	0.1	-4.7	-4.0	-2.5	3.1	0.9	0.2	6.1	8.4	4.9
Jiangxi	30.2	10.5	2.8	-7.9	-9.9	-9.4	1.9	-2.6	-3.4	-0.2	3.7	-2.5
Shandong	22.0	12.5	5.5	-2.8	-13.3	-6.6	-1.5	0.0	-0.5	8.6	7.8	-0.3
Henan	22.8	12.1	4.0	-4.2	-3.2	-6.0	-6.3	-4.5	-6.2	1.2	13.5	-0.4
Hubei	39.7	6.5	3.9	-4.7	-12.2	-8.4	-6.3	-2.5	-5.1	-0.7	13.7	-1.7
Hunan	32.1	9.2	3.3	-4.7	-16.0	-10.1	-1.4	-0.8	-1.0	3.3	13.4	-1.9
Guangdong	20.6	10.2	7.7	-7.7	-7.6	-1.1	-6.0	-9.1	-1.9	5.0	9.4	8.4
Guangxi	19.0	11.1	4.4	-5.8	-21.4	-14.4	-4.9	-5.5	-7.5	3.7	11.6	1.1
Hainan	20.9	1.0	-3.0	-7.9	-7.4	5.9	-22.0	-11.4	-0.7	-10.7	5.8	6.8
Sichuan	25.9	7.8	3.1	-4.3	-12.7	-12.2	-4.1	1.0	1.6	4.3	13.2	-0.3
Guizhou	29.9	14.6	-1.4	-4.0	-11.9	-11.5	-7.8	1.1	-5.1	0.5	10.7	-1.1
Yunnan	15.0	14.3	1.1	-9.0	-6.5	14.0	-18.6	-6.9	-3.8	-1.7	6.5	-0.7
Shaanxi	20.6	14.5	3.5	-8.7	-10.7	-11.7	-1.7	-0.2	-1.2	-8.8	11.4	1.2
Gansu	40.2	19.6	-9.9	-8.9	-13.7	-6.5	-4.4	-3.6	-5.9	3.3	7.8	-2.6
Qinghai	38.0	5.8	-1.9	0.0	-1.9	-2.0	-2.0	6.1	0.0	13.5	6.8	3.2
Ningxia	28.3	9.9	-6.2	-5.2	-25.6	-8.4	12.4	-2.5	-2.2	4.4	-0.4	-3.5
Xinjiang	30.1	8.8	-8.2	-4.9	-8.4	-11.7	-2.2	-4.8	-1.4	20.5	-0.4	1.3

Summary of Provincial Technical Change Rate (%) (Malmquist Index)												
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Beijing	25.7	16.6	3.9	1.6	-2.1	-3.2	1.3	12.3	6.1	11.3	4.1	1.6
Tianjing	14.1	0.8	-4.4	25.8	-6.5	-14.4	-1.2	14.8	3.8	10.1	3.8	2.6
Hebei	23.8	8.8	0.6	12.6	-2.6	-10.6	-1.2	14.8	3.8	10.1	-1.1	12.5
Shanxi	18.6	3.4	-3.7	31.3	-13.9	-16.4	-1.9	8.7	4.1	11.2	1.7	12.5
Inner mongolia	15.3	0.3	-4.9	31.3	-13.9	-17.0	-2.4	6.4	5.0	12.6	6.0	12.5
Liaoning	33.2	3.4	1.7	12.8	-1.1	-11.5	1.9	0.2	6.9	14.7	9.1	12.5
Jilin	21.9	4.2	9.2	-4.5	1.2	-0.7	5.4	-3.4	6.6	17.1	17.1	12.2
Heilongjiang	33.8	2.5	3.1	20.6	-6.4	-21.1	-0.3	1.2	6.8	14.5	8.8	12.5
Shanghai	38.6	10.6	5.7	11.3	-6.6	-12.4	6.3	-0.7	5.2	18.7	16.0	10.5
Jiangsu	32.0	14.8	7.2	-3.5	-1.1	-1.6	6.5	6.0	3.1	17.1	17.1	12.0
Zhejiang	23.4	7.2	-0.8	26.3	-11.7	-16.0	-1.4	11.0	3.6	10.7	1.9	12.5
Anhui	23.0	3.8	4.0	4.2	0.0	-15.6	1.0	-0.9	7.4	15.1	9.6	12.5
Fujian	29.1	12.7	9.9	-4.5	1.2	-1.7	6.6	4.9	3.0	18.1	11.6	4.8
Jiangxi	17.5	1.2	8.6	-4.5	1.2	0.5	4.3	-4.1	8.5	16.2	11.2	12.5
Shandong	32.2	5.5	3.1	4.8	-0.7	-1.1	5.0	5.6	4.9	12.1	4.0	5.2
Henan	26.8	5.0	1.0	18.4	-1.0	-12.3	1.0	1.7	6.6	14.2	7.9	10.5
Hubei	17.5	1.2	8.6	-4.5	1.2	0.5	6.3	4.5	4.8	18.0	17.3	11.6
Hunan	19.3	1.2	0.9	3.8	1.2	-18.4	-2.9	0.2	6.8	14.5	8.5	12.5
Guangdong	32.2	7.9	5.3	1.0	-1.1	-11.2	3.6	-2.2	7.0	18.1	11.7	4.9
Guangxi	18.2	1.2	3.1	-0.4	1.2	-6.8	0.2	-3.5	8.6	16.9	13.2	12.5
Hainan	20.9	1.0	-3.0	2.0	1.2	-12.5	0.5	-5.3	9.4	18.0	14.4	5.2
Sichuan	17.5	1.2	8.6	-4.5	1.2	-0.2	4.8	-4.9	8.9	17.0	13.2	12.5
Guizhou	17.5	1.2	8.6	-4.5	1.2	-2.7	2.3	-3.8	8.5	16.6	12.1	12.5
Yunnan	17.2	0.5	-5.9	10.6	-2.6	-17.8	-3.4	-0.7	7.5	15.5	10.8	12.5
Shaanxi	17.5	1.2	8.6	-3.8	1.2	-0.1	4.9	-4.8	8.8	17.2	13.6	12.2
Gansu	15.8	-0.7	-6.0	30.3	-13.9	-17.3	-2.7	4.9	5.4	12.8	5.2	12.5
Qinghai	14.2	-2.1	-6.0	30.3	-13.9	-15.7	-1.2	14.8	3.8	10.1	-1.1	12.5
Ningxia	18.7	3.1	-3.3	31.3	-7.7	-18.9	-0.9	4.3	5.4	12.3	4.4	12.5
Xinjiang	31.6	2.0	3.8	3.3	-3.9	-13.3	3.1	1.9	1.5	15.6	16.0	11.1

Appendix 4. Summary of Provincial Efficiency Change Rate, Technical Change Rate and TFP Change Rate (Stochastic Frontier)

Summary of Provincial Efficiency Change Rate (%) (Stochastic Frontier)												
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Beijing	-1.0	-1.1	-1.1	-1.1	-1.1	-1.1	-1.2	-1.2	-1.2	-1.2	-1.2	-1.3
Tianjing	-1.8	-1.8	-1.9	-1.9	-1.9	-2.0	-2.0	-2.0	-2.1	-2.1	-2.1	-2.2
Hebei	-1.2	-1.2	-1.3	-1.3	-1.3	-1.3	-1.4	-1.4	-1.4	-1.4	-1.5	-1.5
Shanxi	-1.8	-1.8	-1.9	-1.9	-1.9	-2.0	-2.0	-2.0	-2.1	-2.1	-2.1	-2.2
Inner mongolia	-1.3	-1.3	-1.3	-1.4	-1.4	-1.4	-1.4	-1.5	-1.5	-1.5	-1.5	-1.6
Liaoning	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
Jilin	-1.6	-1.7	-1.7	-1.7	-1.8	-1.8	-1.8	-1.9	-1.9	-1.9	-1.9	-2.0
Heilongjiang	-1.4	-1.4	-1.4	-1.5	-1.5	-1.5	-1.5	-1.6	-1.6	-1.6	-1.7	-1.7
Shanghai	-1.2	-1.2	-1.2	-1.3	-1.3	-1.3	-1.3	-1.4	-1.4	-1.4	-1.4	-1.5
Jiangsu	-1.1	-1.1	-1.1	-1.1	-1.1	-1.2	-1.2	-1.2	-1.2	-1.2	-1.3	-1.3
Zhejiang	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2
Anhui	-1.1	-1.2	-1.2	-1.2	-1.2	-1.2	-1.3	-1.3	-1.3	-1.3	-1.3	-1.4
Fujian	-0.6	-0.6	-0.6	-0.6	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7
Jiangxi	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1
Shandong	-1.1	-1.1	-1.1	-1.2	-1.2	-1.2	-1.2	-1.2	-1.3	-1.3	-1.3	-1.3
Henan	-1.3	-1.3	-1.3	-1.3	-1.4	-1.4	-1.4	-1.4	-1.5	-1.5	-1.5	-1.5
Hubei	-1.5	-1.5	-1.5	-1.5	-1.6	-1.6	-1.6	-1.6	-1.7	-1.7	-1.7	-1.7
Hunan	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.6	-0.6
Guangdong	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Guangxi	-1.1	-1.1	-1.1	-1.1	-1.2	-1.2	-1.2	-1.2	-1.2	-1.3	-1.3	-1.3
Hainan	-1.5	-1.5	-1.5	-1.5	-1.6	-1.6	-1.6	-1.6	-1.7	-1.7	-1.7	-1.8
Sichuan	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Guizhou	-1.0	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.2	-1.2	-1.2	-1.2	-1.2
Yunnan	-0.9	-0.9	-0.9	-0.9	-0.9	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.1
Shaanxi	-1.6	-1.6	-1.6	-1.7	-1.7	-1.7	-1.7	-1.8	-1.8	-1.8	-1.9	-1.9
Gansu	-1.7	-1.7	-1.7	-1.8	-1.8	-1.8	-1.8	-1.9	-1.9	-1.9	-2.0	-2.0
Qinghai	-3.1	-3.2	-3.2	-3.3	-3.3	-3.4	-3.4	-3.5	-3.6	-3.6	-3.7	-3.7
Ningxia	-3.3	-3.3	-3.4	-3.4	-3.5	-3.5	-3.6	-3.7	-3.7	-3.8	-3.8	-3.9
Xinjiang	-1.7	-1.7	-1.7	-1.8	-1.8	-1.8	-1.9	-1.9	-1.9	-2.0	-2.0	-2.0

Summary of Provincial Technical Change Rate (%) (Stochastic Frontier)												
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Beijing	6.3	6.4	6.2	5.9	5.9	5.8	5.8	6.1	6.1	6.0	5.9	5.7
Tianjing	9.0	7.8	7.4	7.1	6.9	6.6	6.4	6.2	6.0	5.9	5.0	4.8
Hebei	1.2	1.2	0.7	0.6	0.5	0.4	0.4	0.3	0.1	0.0	-0.2	-0.4
Shanxi	3.8	3.4	3.2	3.1	2.9	2.8	2.7	2.7	2.5	2.4	2.2	2.1
Inner mongolia	5.1	4.5	4.0	3.5	3.4	3.2	3.2	3.0	2.8	2.3	2.0	1.6
Liaoning	2.5	2.3	2.0	1.9	1.8	1.7	1.8	1.8	1.7	1.5	1.3	1.3
Jilin	2.5	2.2	1.9	1.9	1.7	1.5	1.7	1.6	1.4	1.2	0.4	0.8
Heilongjiang	2.7	2.6	2.4	2.1	2.0	2.0	2.0	1.9	1.7	1.7	1.2	1.1
Shanghai	5.7	5.1	5.1	6.7	6.2	5.0	5.0	4.7	5.0	5.1	5.2	5.1
Jiangsu	0.2	-0.1	-0.4	-0.6	-0.7	-0.8	-0.9	-1.0	-1.1	-1.2	-1.3	-1.4
Zhejiang	3.2	2.8	2.7	2.6	2.8	2.7	2.7	2.5	2.4	2.3	2.1	2.0
Anhui	1.2	0.9	0.2	0.3	0.1	0.1	0.1	-0.3	-0.3	-0.4	-0.5	-0.6
Fujian	2.2	2.0	1.7	1.5	1.4	1.1	1.1	1.1	1.0	0.9	0.8	0.7
Jiangxi	2.3	2.0	1.9	1.7	1.8	1.7	1.9	1.7	1.6	1.6	1.3	1.2
Shandong	0.1	-0.3	-0.5	-0.6	-0.8	-0.9	-0.9	-1.0	-1.1	-1.2	-1.4	-1.6
Henan	0.3	0.0	-0.3	-0.3	-0.6	-0.8	-0.9	-1.2	-1.4	-1.4	-1.7	-1.9
Hubei	0.7	0.2	0.0	-0.3	-0.5	-0.4	-0.4	-0.5	-0.7	-0.9	-1.1	-1.1
Hunan	1.6	1.4	1.4	1.1	1.0	1.0	0.9	0.8	0.7	0.6	0.3	0.2
Guangdong	1.3	0.8	0.7	0.6	1.0	0.8	0.7	0.2	0.1	0.0	-0.2	-0.3
Guangxi	2.4	2.0	1.7	1.4	1.1	1.1	1.0	0.7	0.5	0.3	0.1	-0.1
Hainan	6.6	6.3	6.0	5.3	5.2	5.6	4.5	4.4	4.0	3.5	2.8	3.1
Sichuan	0.7	0.5	0.2	0.0	-0.1	-0.2	-0.3	-0.3	-0.4	-0.5	-0.6	-0.8
Guizhou	3.4	3.5	3.5	3.2	3.3	3.0	2.8	2.8	2.6	2.5	2.5	2.4
Yunnan	3.3	2.9	2.6	2.3	2.2	2.7	2.0	1.7	1.5	1.3	1.1	0.9
Shaanxi	2.4	2.0	1.9	1.8	1.5	1.3	1.2	1.1	1.0	0.7	0.6	0.5
Gansu	4.6	4.4	4.0	3.7	3.5	3.4	3.4	3.2	3.0	2.9	2.7	2.5
Qinghai	9.5	9.2	9.1	8.8	8.8	8.6	8.6	8.5	8.4	8.4	8.5	8.3
Ningxia	7.0	6.6	6.3	6.1	4.8	4.7	5.3	5.1	5.1	5.0	4.7	4.3
Xinjiang	3.9	3.3	2.8	2.5	2.4	2.6	2.5	2.3	2.2	1.9	1.6	1.3

Summary of Provincial TFP Change Rate (%) (Stochastic Frontier)												
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Beijing	5.2	5.3	5.2	4.9	4.8	4.7	4.7	4.9	4.9	4.8	4.6	4.5
Tianjing	7.2	6.0	5.5	5.2	5.0	4.6	4.4	4.2	4.0	3.8	2.9	2.7
Hebei	0.0	0.0	-0.6	-0.7	-0.8	-0.9	-1.0	-1.1	-1.3	-1.4	-1.6	-1.8
Shanxi	2.0	1.6	1.3	1.2	1.0	0.9	0.7	0.7	0.4	0.3	0.1	-0.1
Inner mongolia	3.8	3.1	2.6	2.1	2.0	1.8	1.8	1.5	1.3	0.8	0.4	0.0
Liaoning	1.7	1.5	1.2	1.1	1.0	0.8	1.0	0.9	0.8	0.6	0.4	0.4
Jilin	0.9	0.5	0.2	0.1	-0.1	-0.3	-0.2	-0.3	-0.5	-0.7	-1.6	-1.2
Heilongjiang	1.3	1.2	0.9	0.7	0.5	0.4	0.5	0.3	0.1	0.1	-0.4	-0.6
Shanghai	4.5	3.9	3.9	5.4	4.9	3.7	3.7	3.4	3.6	3.7	3.7	3.7
Jiangsu	-0.9	-1.2	-1.5	-1.7	-1.9	-2.0	-2.1	-2.2	-2.3	-2.4	-2.6	-2.7
Zhejiang	3.1	2.7	2.6	2.5	2.7	2.6	2.6	2.4	2.2	2.1	1.9	1.8
Anhui	0.0	-0.2	-0.9	-0.9	-1.1	-1.2	-1.2	-1.6	-1.6	-1.8	-1.8	-2.0
Fujian	1.5	1.4	1.1	0.9	0.7	0.5	0.4	0.4	0.3	0.2	0.0	-0.1
Jiangxi	1.3	1.1	1.0	0.7	0.8	0.6	0.8	0.7	0.5	0.5	0.1	0.0
Shandong	-1.0	-1.4	-1.6	-1.8	-2.0	-2.1	-2.2	-2.3	-2.4	-2.5	-2.7	-2.9
Henan	-1.0	-1.3	-1.6	-1.7	-2.0	-2.1	-2.4	-2.6	-2.9	-2.9	-3.2	-3.4
Hubei	-0.8	-1.3	-1.5	-1.9	-2.1	-1.9	-2.0	-2.1	-2.3	-2.6	-2.8	-2.9
Hunan	1.2	0.9	0.9	0.6	0.5	0.4	0.4	0.3	0.2	0.0	-0.2	-0.4
Guangdong	1.2	0.7	0.7	0.5	0.9	0.7	0.6	0.1	0.0	-0.1	-0.3	-0.4
Guangxi	1.3	0.9	0.6	0.2	0.0	-0.1	-0.2	-0.5	-0.7	-1.0	-1.2	-1.4
Hainan	5.1	4.8	4.5	3.8	3.7	4.0	2.9	2.7	2.4	1.8	1.1	1.3
Sichuan	0.7	0.4	0.2	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.5	-0.7	-0.9
Guizhou	2.4	2.4	2.4	2.1	2.1	1.9	1.7	1.7	1.4	1.3	1.3	1.2
Yunnan	2.4	2.0	1.7	1.4	1.3	1.7	1.0	0.7	0.5	0.3	0.0	-0.2
Shaanxi	0.9	0.4	0.2	0.1	-0.2	-0.4	-0.5	-0.6	-0.8	-1.1	-1.2	-1.4
Gansu	3.0	2.7	2.2	1.9	1.7	1.6	1.5	1.3	1.1	1.0	0.8	0.5
Qinghai	6.3	6.0	5.9	5.6	5.5	5.2	5.1	5.0	4.8	4.8	4.9	4.5
Ningxia	3.8	3.3	2.9	2.7	1.3	1.2	1.7	1.5	1.4	1.2	0.8	0.4
Xinjiang	2.2	1.6	1.1	0.7	0.6	0.8	0.7	0.4	0.3	-0.1	-0.4	-0.8

Appendix 5. Summary of Regional Efficiency Change Rate, Technical Change Rate and TFP Change Rate (Malmquist Index and Stochastic Frontier)

Annual Average TFP Change Rate (%) for Each Region (Malmquist Index)												
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
EAST	26.049	11.936	0.691	-2.460	-7.523	-5.077	-2.003	-0.971	-1.583	4.804	10.851	3.900
CENTRAL	33.828	8.793	-0.071	-6.091	-10.660	-8.051	-3.123	-2.713	-3.812	3.107	9.927	-2.012
WEST	25.896	11.128	0.092	-5.756	-11.202	-7.697	-5.794	-1.117	-1.102	3.295	9.733	-0.278

Annual Average Efficiency Change Rate (%) for Each Region (Malmquist Index)												
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
East	-2.000	3.707	-2.818	-7.190	-5.353	2.621	-4.799	-5.433	-6.298	-8.503	2.276	-4.442
Central	9.953	5.970	-3.227	-12.437	-8.779	4.180	-4.282	-3.728	-9.662	-10.407	-0.186	-12.497
West	6.180	10.015	-4.068	-6.717	-9.828	-0.504	-8.104	1.456	-7.991	-11.034	-2.018	-11.255

Annual Average Technical Change Rate (%) for Each Region (Malmquist Index)												
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
East	28.777	8.125	3.677	5.680	-2.019	-7.149	3.029	4.832	5.065	14.646	8.546	8.832
Central	21.991	2.673	3.395	8.602	-1.734	-11.104	1.301	1.129	6.480	15.095	10.203	11.969
West	18.698	1.019	4.592	2.154	-1.331	-6.023	2.492	-2.326	7.522	16.137	12.112	12.328

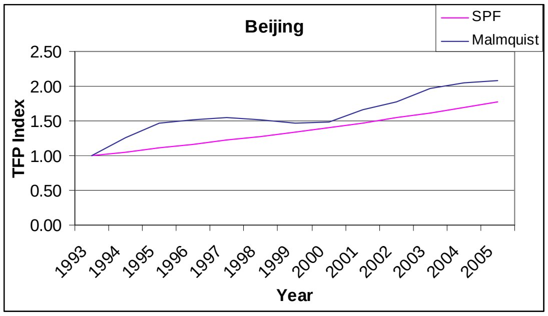
Annual Average TFP Change Rate (%) for Each Region (Stochastic Frontier)												
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
East	0.869	0.537	0.305	0.155	0.086	-0.054	-0.144	-0.307	-0.449	-0.580	-0.779	-0.927
Central	0.540	0.202	-0.086	-0.281	-0.448	-0.540	-0.582	-0.773	-0.936	-1.097	-1.398	-1.540
West	1.570	1.265	0.997	0.760	0.626	0.593	0.393	0.260	0.131	-0.011	-0.207	-0.386

Annual Average Efficiency Change Rate (%) for Each Region (Stochastic Frontier)												
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
East	-0.818	-0.831	-0.846	-0.860	-0.874	-0.889	-0.904	-0.920	-0.935	-0.951	-0.967	-0.984
Central	-1.185	-1.205	-1.226	-1.246	-1.268	-1.289	-1.311	-1.333	-1.356	-1.379	-1.402	-1.426
West	-0.824	-0.838	-0.852	-0.867	-0.882	-0.897	-0.912	-0.927	-0.943	-0.959	-0.975	-0.991

Annual Average Technical Change Rate (%) for Each Region (Stochastic Frontier)												
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
East	1.686	1.368	1.150	1.015	0.961	0.835	0.761	0.613	0.486	0.371	0.188	0.057
Central	1.725	1.407	1.139	0.965	0.819	0.749	0.729	0.560	0.419	0.282	0.004	-0.115
West	2.394	2.103	1.849	1.626	1.508	1.490	1.305	1.187	1.073	0.947	0.768	0.605

Note: East area includes the following regions: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi and Hainan. The central area includes Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan. The west area includes Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xingjiang.

Appendix 6. Plots Comparing Provincial TFP Indexes across methodologies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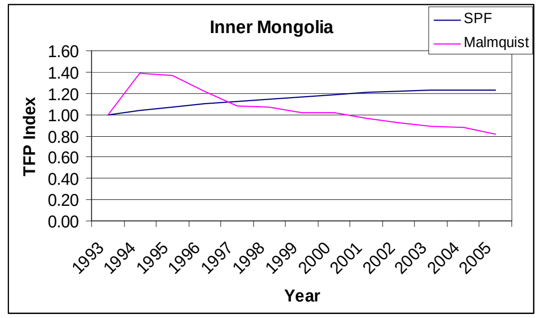
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year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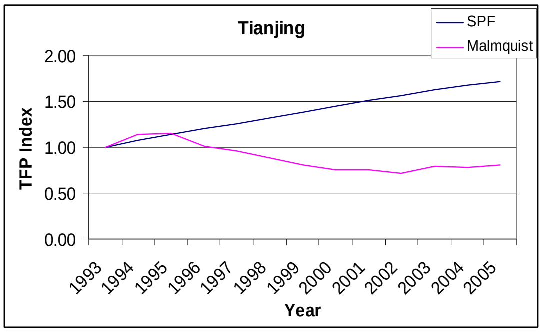
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year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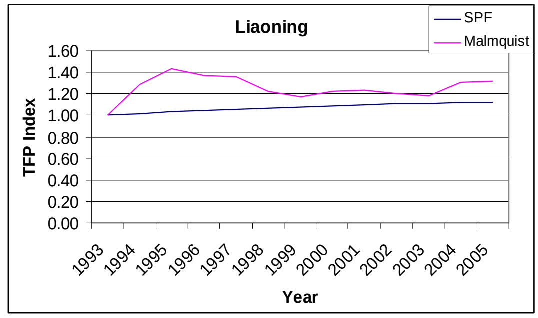
Year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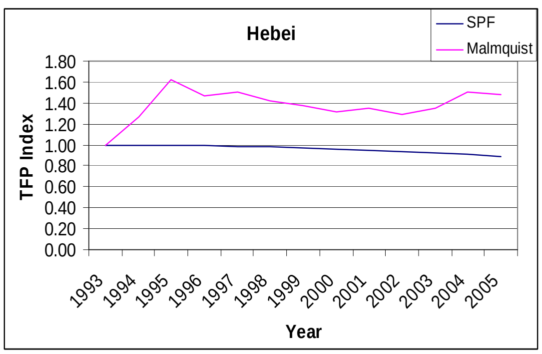
0.00
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year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Malmquist
TFP Index
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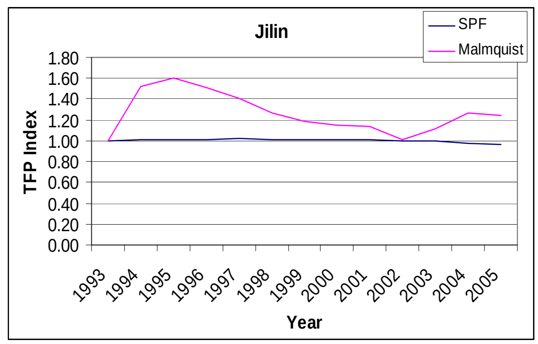
0.20
0.00
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year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SPF
Malmquist
TFP Index
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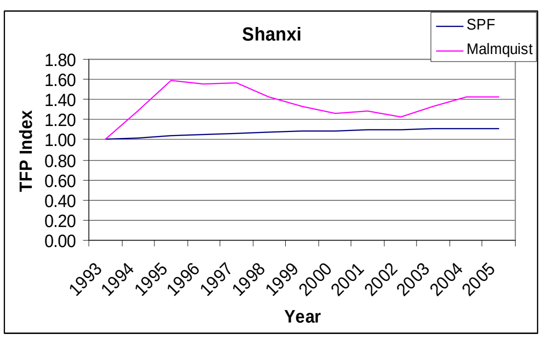
0.00
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year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SPF
Malmquist
TFP Index
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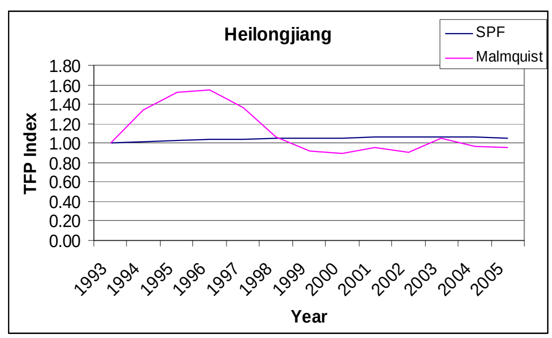
0.00
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year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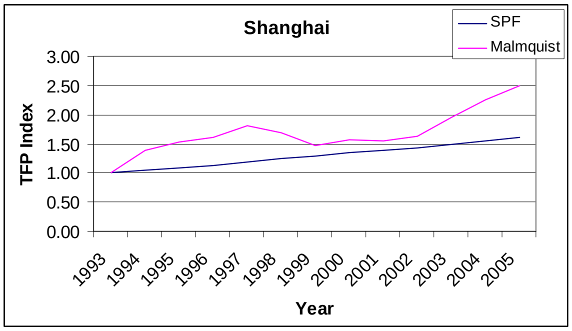
Year


Shanghai
SPF
Malmquist
TFP Index
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2.50
2.00
1.50
1.00
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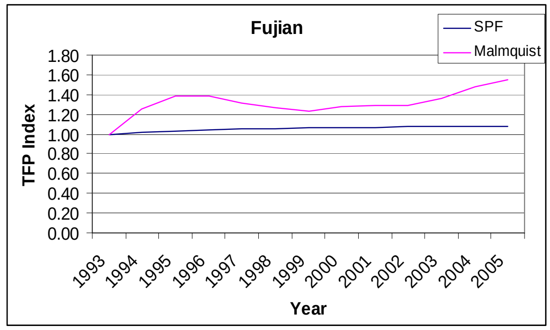
0.00
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year


Fujian
SPF
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TFP Index
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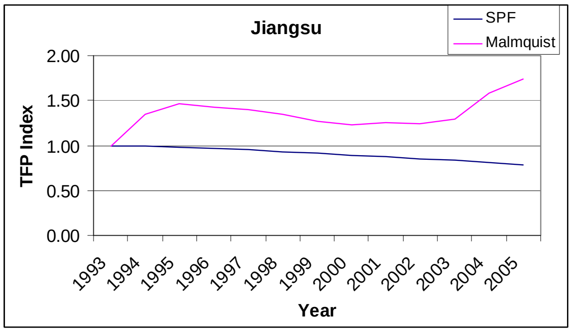
0.00
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year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SPF
Malmquist
TFP Index
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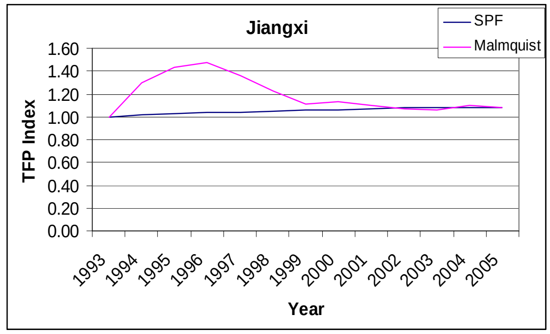
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year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Malmquist
TFP Index
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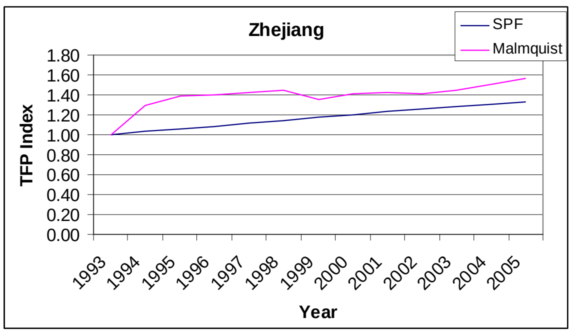
0.00
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year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Malmquist
TFP Index
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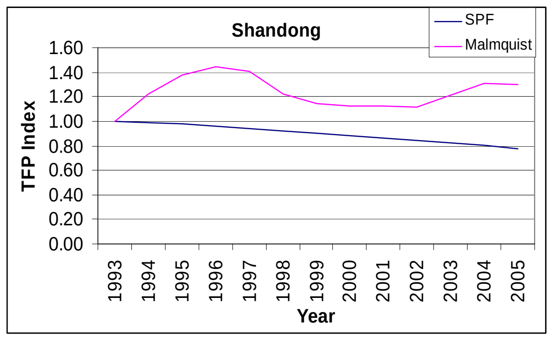
0.00
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year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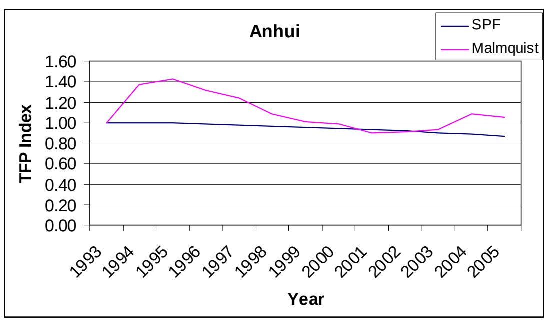
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year


Anhui
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Malmquist
TFP Index
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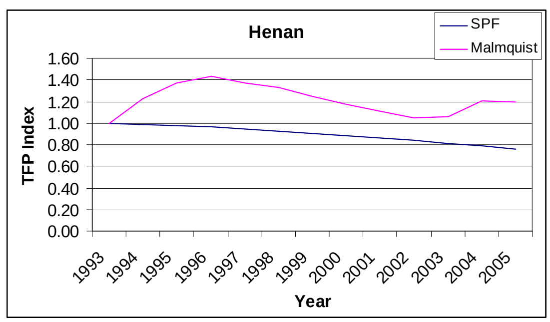
0.00
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year


Henan
SPF
Malmquist
TFP Index
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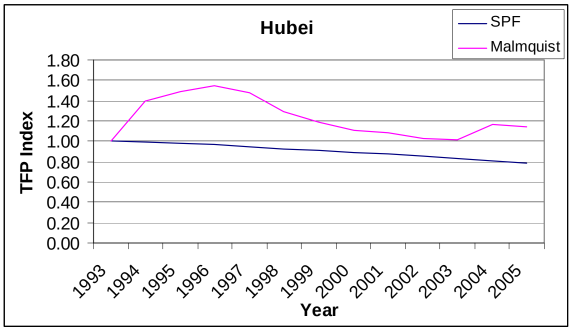
0.00
1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Year


Hubei
SPF
Malmquist
TFP Index
1.80
1.60
1.40
1.20
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0.80
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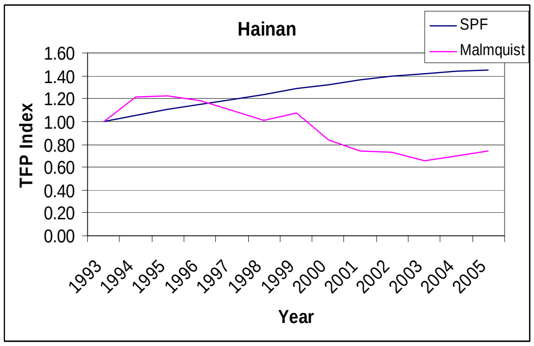
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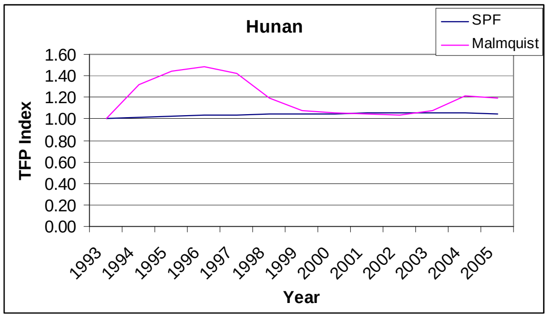
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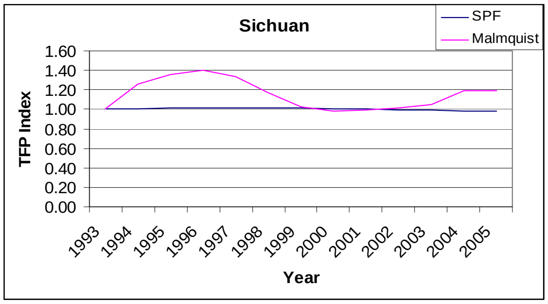
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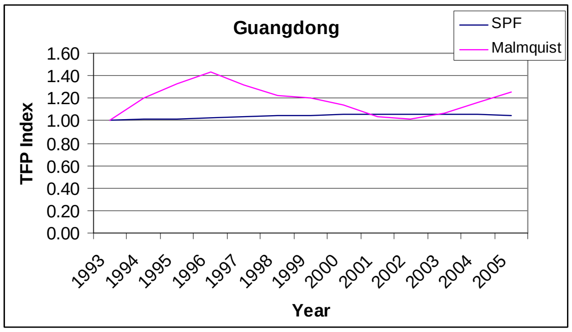
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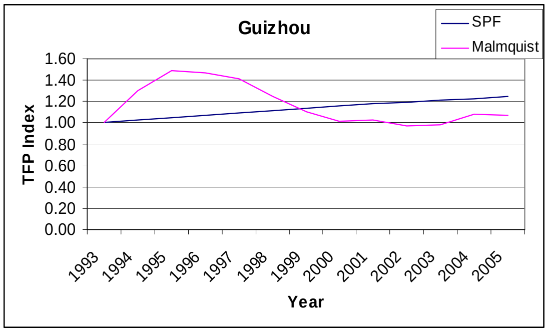
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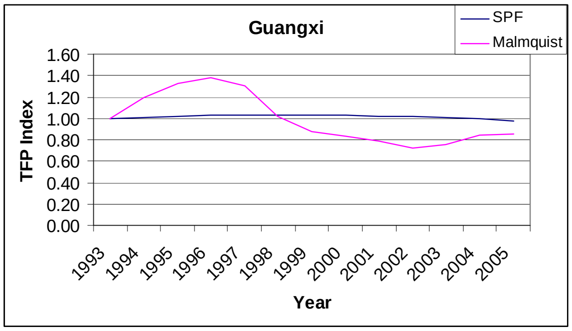
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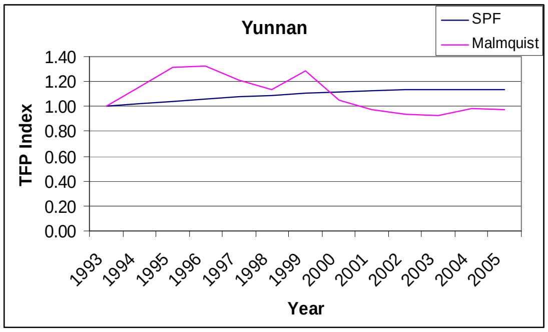
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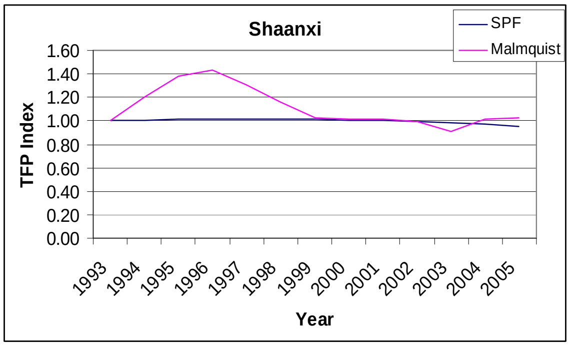
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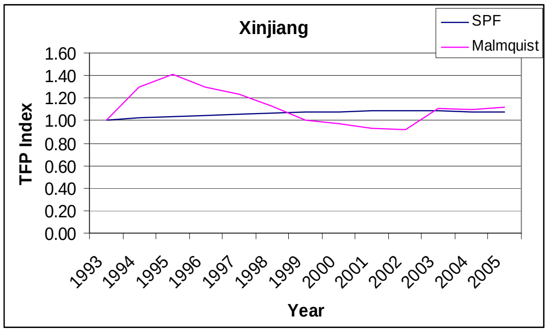
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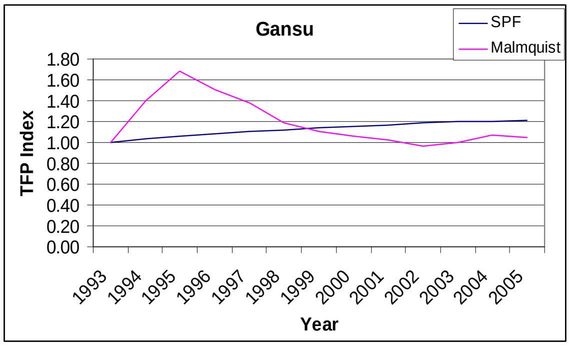
Gansu
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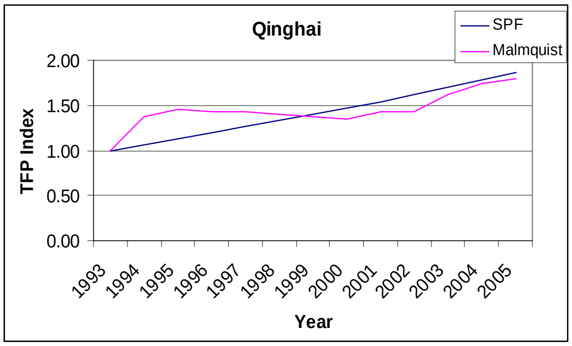
Year


Qinghai
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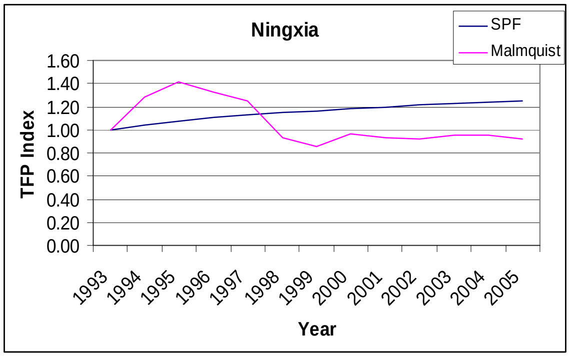
Year


Ningxia
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Malmquist
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